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PRINCIPLES
OF
MODERN CHEMISTRY,

SYSTEMATICALLY ARRANGED,

BY

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TRANSLATED FROM THE GERMAN;

WITH

NOTES AND ADDITIONS, CONCERNING LATER DISCOVERIES,
BY THE TRANSLATOR, AND SOME NECESSARY TABLES.

ILLUSTRATED BY PLATES.

VOLUME I.

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P R E F A C E.

THE book which is here offered to the public in English dress, is an abstract made by the late celebrated Dr. Gren himself, in the year 1796, from his *System of Chemistry, Halle, 1794*, in 4 vols. 8vo. the most complete and systematical work ever published on this science.—It was not destined, as he says himself in his Preface, to be a *mere skeleton of that larger work, but to be useful without it, and to form a complete introduction to Chemistry.*—Hence all the principal experiments have been circumstantially described, and all the fundamental and leading principles properly explained.

WITHOUT anticipating the opinion of the public, or encroaching upon the department of the sober Critic, it may be said that this book, small as it is, embraces the whole of this science in the most systematical order, pro-

ceeding from the first notions, step by step, to the most complicated doctrines, and arranged with the greatest clearness and precision.—Some parts, however, of the *vegetable* and *animal kingdom*, more interesting to the Physician than the public at large, have been rather shortly treated of; but they have been explained in a very ample and masterly manner in the second volume of his System of Chemistry.—Besides, the Author declares, that his chief attention, in writing it, was bestowed on the *practical* use and application of Chemistry. For this reason he has introduced a number of valuable matters relating to *pharmacy, arts, manufactures, and the operations of common life*; such as the making of *glass, pottery, enamelling, making of sugar, starch, art of dyeing, bleaching, making of wines, brandy, beer, vinegar, baking of bread, production of nitre, refining metals, &c.*

To those, who for the first time study this science, it is immaterial to state what new discoveries they may expect from this work; besides that it would require too long a detail. But the experienced Chemist, who honours it with a perusal, will readily find a number of new lights, hints, and improvements,
modestly

modestly proposed, without the least affected shew of novelty.

It remains to be observed in this place, that Dr. *Gren*, at the time of writing this work, had renounced the *Atomistical System* of Natural Philosophy, which in latter times has been extended to great subtleties by *Le Sage* and *De Luc*; and that, in its stead, he has adopted the *Dynamic System*, illustrated by *Kant* in his *Metaphysical Elements of Natural Philosophy*.—According to the former, 1st. matter fills its *space* merely by its *existence*; 2dly, it is *absolutely impenetrable*; 3dly, its *division* can be carried to a certain length only, ending in *atoms*, which, though extended, are not farther divisible; 4thly, there are *empty interstices* between the atoms; 5thly, the particles of elastic fluids, as air, vapours, caloric, &c. do not touch each other, and consequently they form what is called *discrete fluids*; 6thly, the *rarity* or *density* of a body depends solely on the quantity of empty interstices in a certain volume of space occupied by the matter constituting that body.—On the other hand, according to the *Dynamic System*, matter fills its space by its *primitive powers of attraction and repulsion*; its impenetrability is only *relative*;

it is *divisible in infinitum*; it fills its space as a *continuum*, or with *continuity*, so that the *objective vacuum* is a mere imaginary being, consequently there are no *discrete fluids*, and even the particles of caloric and light form a *continuum*; lastly, the *greater* or *less density* of a body is only an expression indicating the *greater* or *less intensity* of the *primitive, attractive, and repulsive powers*; which constitute the nature of matter, and which must decrease together with the *extension* of a certain body, according to certain laws; and therefore matter is supposed, even at the greatest rarity or least density, to fill its space with continuity.

FROM these tenets of the *dynamic doctrine*, the expressions *continuum*, *continuity*, *discrete fluids*, &c. not used in this country in that sense, occur in the earlier part of the present book, which the Translator could not suppress without altering the sense of the text.

BESIDES, it is well known, that, in the *System of Chemistry* quoted above, the Author did not so much adhere to the old *phlogistic system*, as was objected by some, but rather that he has framed a system of his own, which he called *ecclectic* (mentioned in this work, § IX. Introd.); though he there explains every
phenomenon,

PREFACE. v

phenomenon, not only according to his own doctrine, but also *historically*, according to that of both the *phlogistian* and *anti-phlogistian philosophers*.—To that *ecclectic* system the Author adhered to his death; but the reader is requested to observe, that in the present work Dr. *Gren* has merely stated the grounds of his favourite chemical creed, and continued throughout the rest to explain all the phenomena treated of according to the modern **ANTI-PHLOGISTIC SYSTEM** in the strictest sense.—Consult § 213.

Thus far concerning the original. The Translator will now state what he has done in the present publication.

I. HE has endeavoured to give the meaning of the text as closely, faithfully, and literally, as the nature of the two languages would allow. He has taken no liberties with his Author; only, in a very few places, he thought proper to transfer a line or two from the Author's own larger book, or in notes, besides a few of his own, marked *Ed.*—He has also studiously retained the references in the §§, or rather increased their number, in order to assist the recollection of the reader.

II. SINCE the German publication of this work, some valuable discoveries have been made in the science. All of them do not come within the compass of an elementary treatise. Such as may have been occasionally added in notes, distinguished by *Ed.* from those of the Author. The new earth, *glucine*, or rather *glycine*, the two new metals, *tellurium*, or sylvanite, and *chrome*, have been added in the text in their proper places.

III. WITH regard to *terminology*, the Translator has made use of the *new Nomenclature*, as proposed by the French Chemists, and translated into English, under the title, *Method of Chemical Nomenclature, proposed by De Morveau, Lavoisier, Berthollet, and Fourcroy*. Translated by James St. John, M.D. 8vo. London, 1788. — Well aware of some inaccuracies observable in that Nomenclature, and of the improvements that might be made in it, he thought it more reasonable to keep, as it were, to a certain *standard*, now almost generally adopted, than to fall into the fashionable mania of fabricating or adopting new terms. For if we go on, as some of the learned in this and other countries do, there is great danger that, after ten years, no Chemist will understand another.—

ther.—If the Translator's orthography should be objected to, although he is able to defend it against all cavils, he is far from entering into any grammatical discussion. Surely, losing time about words is not the way of improving any science!

By this, however, it is not meant to preclude the farther improvement of the new Nomenclature, of which it is certainly capable; but, instead of adopting directly new-framed terms in books, let them be fairly proposed, as Dr. *Pearson* has done, supported by proper reasons, wherever opportunity presents itself; and when a sufficient number of facts, discoveries, and arguments for that purpose are collected, it will then be time to offer to the *chemical* public a *corrected* Nomenclature for their approbation.

By way of example, Dr. *Gren* himself has in this work proposed and used the terms *muriatous* instead of *muriatic*, and *muriatic* instead of oxygenated *muriatic acid*, by fair analogy from *fulphureous* and *fulphuric*, *nitrous* and *nitric acids*, &c. because what is now called *muriatic* is not a perfect, but only an imperfect acid, § 534; while, on the other hand,

hand, the oxygenated muriatic is the perfect acid of that kind, § 567. In consequence of this, by the same analogy, he uses *muriatous pot-ash*, *muriatous soda*, &c. instead of *muriat of pot-ash*, *of soda*, &c. and *muriat of pot-ash*, &c. instead of oxygenated muriat of pot-ash now employed.—Certainly the terms *oxygenated muriatic*, or *oxy-muriatic acid*, are not very successfully contrived, are long, and imply a tautology. The first signifies only *acidified muriatic acid*, and the other *acid muriatic acid*.

ANOTHER instance—besides many others occasionally mentioned in the book—the metallic oxyds, according to §§ 1220—27, should not be called *sulphat*, *nitrat*, *muriat of iron*, *copper*, *tin*, &c. but *sulphated*, *nitrated*, *muriated oxyd of iron*, *copper*, *tin*, &c.—All these improvements, however, have been only pointed out by the Translator; and the modern Nomenclature, hitherto in use, has been preferred, in order to prevent being misunderstood.

FEARING to be found guilty of having himself trespassed the rules just before recommended, the Translator begs leave to observe, that according to his Author's own literal expressions, he has introduced the words *mingled* instead

instead of the complex terms mechanically united, and *mixed* instead of chemically combined; as also *liquid fluids*, to preserve the generic word *fluid*, and to distinguish them from another *species*, called *elastic*. Several more of that kind are here omitted for the sake of brevity. But, besides that those terms have been sufficiently defined, they are constantly used in the same sense, and are more precise; hence, it is hoped, they will be tolerated by men who know how to estimate precision and brevity of language in a scientific book, where simplicity is as much required as equivocation of terms to be avoided. The words *oxygen*, *hydrogen*, *azot*, *carbonic acid*, &c. were not long since offensive to many individuals, but are now generally accepted.

THERE also does not appear any reason for disregarding popular expressions, when they convey to the mind any proper idea clearly and distinctly, such as *glowing*, *glow-heat*, &c. literally translated from the Author, which certainly are less equivocal and more distinct than *ignition*, *ignited*, &c. since a body may be ignited to a high degree without reaching even that of a *low red-heat*. However, these and many others the Translator did not dare

to employ; and at this opportunity he begs leave to say, that he has suppressed a number of good, clear, and energetic expressions, to avoid giving offence to the delicate ear of the over-chaste Critic.

ONE word more on this head. The reader will observe, that at the beginning of the work, the *ancient terminology* has been used; but, after every particular substance and its constituent parts had been explained, its name has been given according to the *new Nomenclature*, and then for some time both have been promiscuously used; however, so, that towards the latter part, the preference has almost always been given to the new Nomenclature.— This has been purposely observed by the Author himself, but rather more so by the Translator; and the reason of it is, that in common life, even among the Druggists, the old names of the various substances and *præparata* are better known than the new ones, and that the reader may gradually, and without any trouble, become acquainted with both Nomenclatures.

For a similar motive, the *Latin names*, inserted by the Author in brackets, though they seem

seem useless in an English translation, have not been always erased, for the sake of those who, acquainted only with the new style, may, after some time, turn their attention to the works of former Chemists mostly written in that language, and some of which are still valuable on many accounts,

IV. THE German original having been written to be commented on in public lectures, where the chemical apparatus is exhibited in making the experiments, had no Plates. But as the subject of this work has been treated and explained by Dr. Gren so clearly, and in so easy a manner, that any common understanding may be sufficiently initiated in this science without much farther assistance, the Publishers went liberally, hand in hand, with the wishes of the Translator, to gratify the *Amateur*, and had seven Plates engraved by the masterly hand of *Lowry*.—The *first six* represent the most necessary and useful *chemical instruments*, and belong to the first volume: a *seventh* was added to the second, exhibiting a sufficient number of specimens of the new *chemical symbols*, progressively from the primitive and simple to the compounded.

V. AFTER

V. AFTER the close of the book, the Translator made free to offer, in the *Appendix*, distinguished from the main work by different types, some matters, which he hopes will be acceptable to the reader. They relate to the *Tables of Affinities*, the new *Chemical Symbols*, the *specific and absolute Gravity of Bodies*, the comparison of *Fahrenheit's* with *Reaumur's Thermometer*, of the former *French Measures and Weights*, and of the present *Metre, Litres, and Grammes*, recently adopted in *France* for measures and weights, with the English.—Lastly, a small *Chemical Library* was added.—He flatters himself the reasons for doing so, alleged under each of these heads, will be sufficient to excuse him for thus intruding upon the public.

NOTHING has been said in particular on the new *Chemical Nomenclature*, because the Author himself has sufficiently explained it in the course of the work; and the reader will be much better informed by referring to Dr. *Pearson's Translation of the Table of Chemical Nomenclature proposed by Guyton, Lavoisier, &c.* 2d Edit. Lond. 1799. 4to.

VI. FINALLY,

VI. FINALLY, it may seem rather strange to meet with so large an Index at the end of so small a book; but it was made to answer two purposes.—First, it should be as complete as possible, to assist the memory, and to facilitate the finding of any subject treated of in the work.—Secondly, it was intended to serve in lieu of a compendious Dictionary of both the old and new Nomenclature; the former, as mentioned before, being still most known in common life, and the latter only among the learned. The Translator has many times witnessed an article being asked for in the new style, and the shopman not being able to comprehend what was meant; while, on the other hand, the pupil of modern Chemistry, unacquainted with the old name of the substance, was unable to explain what he wanted.

THIS inconvenience is easily remedied by an Index of that kind.—*Sulphat of magnesia* is wanted, for instance: by referring to Vol. I. p. 233, quoted in the Index, its synonymous term, *Epsom-salt*, is found. Or, on the contrary, *tartar emetic* is prescribed by the Physician, by referring to Vol. II. p. 390, again quoted in the Index, it is found to be the *antimoniated*

antimoniated tartrate of pot-ash. For this very reason the *London College of Physicians* have prudently accompanied their *Pharmacopœia* with a double index.—It is on account of these circumstances that the Index has turned out rather more copious than might be thought necessary.

SOME inaccuracies have, no doubt, unwillingly escaped the industry of the Translator. These, and some typographical errors, not noticed in due time, the candid reader is requested kindly to forgive.

THE TRANSLATOR,

LONDON,
15 February, 1800.

CONTENTS.

CONTENTS

OF THE

FIRST VOLUME.

INTRODUCTION	Page
	I

CHAPTER I.

Preliminary Matters.

Elements of Bodies	17
Mechanical Division and Separation	25
Primitive Powers, and the Forms of Matter depending thereon	28
Chemical Affinities	46
Chemical Operations and Instruments	50
Solution	58
Precipitation	67
Fusion	69
Volatilization	77
Distillation	81
Pneumatic Apparatus	88
Sublimation	91
Chemical Instruments, Balances, Weights, &c.	92
Re-agents	99

CHAPTER II.

Of the more common, simple, and compound Substances.

Caloric	101
Light—Phlogiston	121
Phenomena of Combustion in atmospheric Air	126
Composition of atmospheric Air	129
Vital Air, or Oxygen Gas—Oxygen	130
Theory of Fire and Combustion	135
VOL. I.	b Azotic,

	Page
Azotic, or Nitrogen Gas—Azot	143
Eudiometer	144
Carbonic Acid Gas—Carbonic Radical	147
Water—Hydrogen—Inflammable Air, or Hydrogen Gas	150

CHAPTER III.

Of Salts in general.

General Character of Acids and Alkalis	165
Acids	168
Alkalis	173
Neutral Salts	179

CHAPTER IV.

Of Earths.

Of Earths in general	181
Middle Salts	182

Of Earths in particular.

Siliceous Earth—Glaſs	183
Calcareous Earth, or Lime	188
Magnesia, or Talcum	191
Alumine, or Argillaceous Earth	193
Use of Clay for Pottery-ware	195
Barytes, or Ponderous Earth	201
Strontian-Earth	203
Circon-Earth, or Jargon of Ceylon	205
Austral-Earth	<i>ibid.</i>
Glucine (<i>additional</i>)	208

CHAPTER V.

Mineral Acids, and their Combinations with Alkalis and Earths.

Carbonic Acid	207
Sulphur	219
Sulphuric Acid	223
Sulphureous Acid	241
Sulphur with other Substances	245
Decomposition of the Sulphuric Acid	253
Nitric Acid	259
Nitrous Acid	268
Nitrous Gas—Gaseous Oxyd of Azot	271
Total Decomposition of the Nitric Acid—	
Detonation	278
Muriatic Acid	287
Oxygenated Muriatic Acid	305
Nitro-muriatic Acid	312
Fluoric	

CONTENTS.

xvii

	Page
Fluoric Acid	313
Boracic Acid	319

CHAPTER VI.

Constituent Parts of Vegetables.

General Examination of Vegetables	327
Their Analysis by Means of Fire	330

Particular Examination of the constituent Parts of Vegetables, § 651.

Essential Salts of Plants	346
Tartar—Tartareous Acid	341
Salt of Wood-Sorrel—Oxalic Acid	359
Citric Acid	366
Malic Acid	370
Concerning other four Juices of Plants	371
Benzoic Acid	372
Gallic Acid	376
Sugar	379
Mucilage of Plants	385
Refin	387
Gum-Refin	390
Gluten	391
Starch	392
Albuminous Matter of Plants	395
Fat Oil	396
Elastic Refin	405
Ethereal Oil	407
Camphor	416
Acrid Vegetable Matter	420
Narcotic Matter of Plants	422
Fibrous Part of Vegetables	423
Extracts from Plants	424
Vegetable Pigments	
General Principles of Dyeing	426
Indigo	434
Litmus	442
Arnatto	443
Sap-Colours	444
Lake-Colours	ibid.
Of Bleaching	446

SIX PLATES, representing the most useful Chemical Instruments, and their Explanation.

ERRATA.

ERRATA.

<i>Page</i>		<i>Line</i>		<i>Read</i>
18	—	27	<i>porpyhry</i>	— <i>porphyry.</i>
146	—	13		<i>dele gangues.</i>
<i>Page</i>		<i>Line</i>		<i>Read</i>
332	—	21	<i>cream of lime</i>	— <i>milk of lime.</i>
384	—	27	<i>Yaquin</i>	— <i>Jacquin.</i>
436	—	5	<i>Guatamala</i>	— <i>Guatemala.</i>

TO THE BOOK-BINDER.

The first Six Plates to be bound at the end of the first volume.
The Tables of Explanation to front their respective plates.

The Seventh Plate (guarded) in the second volume, after
page 466.

INTRODUCTION.

I.

CHEMISTRY (*Chemia*) teaches us the reciprocal actions of natural simple substances, the composition of bodies from them according to their proportions, and likewise the manner of separating or combining them again to compound new bodies.

Synonyma: *Spagiric Art, Hermetic Art, Pyrotechny.*

Chemistry is considered as a *Science*, and as an *Art*.

II.

Chemistry is therefore a part of *Natural Philosophy*. Its objects are all the beings of the sensible world; its basis is *Experience*, from which by regular conclusions it deduces the *Theory*, which connects the facts to form a scientific system. Its purpose is not merely to consider the nature and mixture of bodies, but also to make them useful to our wants by means of suitable operations.

The particular use made of chemistry as an art, has given rise to various appellations, as *Halurgy* or *Halotechny*, *Lithurgy*, *Hyalurgy*, *Phlogurgy*, *Zymotechny*, *Metallurgy*, *Docimasy*, or *Art of Assaying metals, and metallic ores*.

Alchemy has nothing in common with our science, but the similarity of name. It is indeed the mother of Chemistry, but it is not the fault of the daughter, if her mother is absurd.

III.

Chemistry, considered as a scientific system, had its beginning only in modern times. The discovery of facts on which Chemistry is grounded, is the mere work of the senses; and it is no wonder that ages could pass, before either by accident or necessity, attention was paid to some of those facts; and still more so, before so many of them were collected, as could furnish the basis of a scientific system.

The necessities of even the first inhabitants of the globe, could not but force them to attempt various alterations with certain bodies to satisfy those wants; and these must have naturally been augmented, in proportion as, by the increase of nations on confined territories, the means of subsistence were rendered difficult, and the manners of living multiplied. The satisfying of these wants absolutely presupposes various chemical operations in the alteration of the mixture of bodies. *Baking of*
5 *bread,*

bread, casting of iron, making of wine, &c. are truly chemical operations. Yet the chemical operations, rendered necessary by these wants, how various soever they may have been even with the nations of remote antiquity, and were really so according to the remaining dates and monuments of history, rested all, no doubt, on a mere empirical practice.

Thus also was the Chemistry of the Egyptians, which in the history of sciences in general, and that of Chemistry in particular, is always first mentioned, nothing else, in fact, than an imperfect art, a mere practice of certain chemical operations, as is perhaps at present the case with the Chinese, and with our common artificers. No doubt the Egyptians were, before other nations of high antiquity, acquainted with a great number of such experiments, and practising such operations, as may be called chemical. Their country has undoubtedly, in the course of time, given birth to the name *Chemia*.

But it was chiefly the Christian Mystics, and the New-Platonics, that occasioned the high opinion of the chemical knowledge of the Egyptians; and the propensity of man to the wonderful and mysterious, has given currency to this belief. Several *alchemical writings*, that were attributed to some remarkable persons of the highest antiquity, as to *Hermes*, are spurious productions of those New-Platonics.

Plutarch says (*Isis et Osiris*, page 364. C.) ἔτι τὴν Αἴγυπτον ἐν τοῖς μάλιστα μελάγγειον οὖσαν, ὥσπερ τὸ μέλαν τοῦ ὀφθαλμοῦ, ΧΗΜΕΙΑ καλοῦσι. Præterea Ægyptum, quæ vel maxime nigram habet terram, tanquam nigram oculi partem, *Chemia* vocant. In the *Psalms* (cv) Egypt is called *Terra Chami*.

Chemia signifies therefore, according to the original sense, the *black of the eye*; but also the *hidden or secret* has been hieroglyphically signified by this word, as in the Arabic, according to *Bochart*, χημᾶ signifies *occultare*. In latter times only, when among the *New-Platonics*, the phantoms of *Theosophy*, *Magic*, and *Alchemy*, occupied the authors, the term *Chemia* was made use of to signify the *Science of Nature*, or rather *Magic* (διδασκαλίαν πάλιν τῶν τῆς φύσεως ἔργων) according to *Zosimus Panopolita*, quoted by *Borrichius* (*De ortu et progr. chemiæ*, p. 12.) and especially the *art of making gold and silver* (χημεία ἡ τοῦ ἀργύρου, καὶ χρύσου καλαιοσυνή according to *Suidas*). Before the *New-Platonics*, this word is never mentioned under such signification, neither by the Greeks nor by the Romans. *Julius Maternus Firmicus*, who lived in the age of *Constantine the Great*, is the first author among the *New-Platonics*, where the word *Alchemy* appears, and of which he makes mention as of a very well known art. He says (l. iii. *Matheseos*, c. 15.) “ Si fuerit hæc domus Mercurii, dabit *Astronomiam*; si *Veneris*, *cantilenas et lætitiā*; si *Martis*, *opus armorum et instrumentorum*; si *Jovis*, *divinum cultum, scientiamque in lege*; si *Saturni*, *Scientiam Alchemiæ*.”

IV.

The problem of making gold and silver by art, took its origin only among the *New-Platonic sect* of philo-

philosophy, and the name of this pretended art appeared, for the first time, in the fourth century after Christ. Engaged by this, the pretended investigators of nature soon lost sight of all other objects; the transformation of metals was the only central point round which the then chemists, if we may call them so, were revolving; their writings became obscure and full of mysteries, and for that very reason, even in such phenomena as they have occasionally observed, of no use in the true Chemistry, which inquires into nature.

To these authors belong *Jamblichus* and *Heliodorus* (in IVth Cent.) *Zosimus Panopolita*, *Synefius* and *Olympiodorus* (in Vth Cent.) *Stephanus Alexandrinus* (in VIIth) *Michael Psellus* in the XIth Cent.

V.

After the Sciences had been oppressed in the West, by barbarity, the *Arabians* proved to be their cultivators, and inherited from the latter Greeks the passion for alchemy; their inclination to the marvellous made them the most zealous promoters of every branch of Theosophy. It is in their writings, we find first the application of *alchemical operations* to the preparing of medicines, and several *chemically* prepared medicaments, so that we are entitled to trace from the Arabs the origin of *Medicinal Chemistry*.

Geber or *Dschafar* (born 702, d. 765) *Rhazes*, or properly *Muhammed Ebn Sacharjah Abu Bekr Al-Rafi* (in the Xth Cent.); *Avicenna*, or *Al Huffain Abu Ali Ben Abdallah Ebn. Sina* (born 978, d. 1036); *Mefne*, the younger (died 1028), are among the Arabian chemists.

VI.

When in the thirteenth Century the Christians in the West began again by degrees to pay more attention to Chemistry, there were then no other Chemists to be found, than the operative Alchemists; and the Philosophers-stone was the whole aim of their endeavours, notwithstanding the encouragements which the study of nature had received, and the increase of knowledge which the greater communication between nations by means of commerce and navigation had procured.—The scholastic system prevailing in philosophy was unable to improve the physics and chemistry, learnt from the Arabs, or to cultivate them with the proper method, by experimental investigation of bodies.

We should, however, not be too ungrateful towards this middle age, as it is called, nor judge of the sum as well as of the value of its practical and truly useful knowledge by the rubbish and nonsense of its speculative learning.

The practical knowledge, which constitutes the true ground-work of all science of nature, had nevertheless

ances were rendered obscure by the obstacles, which their alchemical labours opposed to true Chemistry.

Albert. von Bollstaedt (born 1193, d. 1280) *Roger Bacon* (born 1214, d. 1294) *Raimund. Lullius* (born 1235, d. 1315) *Arnold. of Villanova* (born 1250, d. 1313) *Isaac Holland*, and the pseudonymous *Basilus Valentinus*, belong to the authors of this age.

VII.

In the fifteenth century, philosophy was greatly enlightened by the study of the originals of ancient Greek learning, and these advances received besides from the then invented art of printing a very powerful support, and an uncommon facility of being propagated. Many learned men of better understanding began then to dispossess the *scholastic* philosophy of its credit, to disperse more effectually the clouds of superstition, and to tread the paths of experimental inquiry into nature,

Many particular chemical arts and operations had even then advanced to a high degree of perfection, of which the description of the metallurgic labours given by *George Agricola* (born 1494, d. 1555) may serve as an instance. Yet, notwithstanding this, the discoveries of many deserving men, in other branches of natural science, were not so beneficial to chemistry as they might have been. In spite of the rapid and laudable progress of the former, assisted by the labours of *Galileo* (born 1564, d. 1641)

John

John Keppler (born 1571, d. 1630) *René des Cartes* (born 1596, d. 1650) *Francis Bacon, of Verulam* (born 1560, d. 1626) *Otto von Guericke* (born 1602, d. 1686) *Evangelista Torricelli* (born 1608, d. 1647) *Robert Boyle* (born 1626, d. 1691) and *Isaac Newton* (born 1642, d. 1727.) Chemistry could not then rescue itself from the Mystics and Alchemy.

The famous *Aureolus Philippus Paracelsus Theophrastus Bombastus von Hohenheim* (born 1493, d. 1541), who as to ostentation and lies has surpassed all his predecessors in Alchemy, and who to the chimerical transformation of metals has added the phantom of an universal medicine, still found imitators and defenders; though some of them, of whom I mention only *John Baptist Van Helmont* (born 1577, d. 1644) *Rudolph. Glauber* (who wrote about the middle of the 17th century) and *John Kunkel von Loewenstern* (born 1630) did, by their particular labours and discoveries, a great deal of useful service to genuine Chemistry.

The beneficial influence of the Paracelsians on the discovery, introduction and preparation of a great many very efficacious medicines, and on laying the foundation to a medicinal chemistry, and chemical pharmacy, ought not indeed to be disregarded. Two men, Father *Athanasius Kircher* (born 1599? d. 1680) and the learned *Hermannus Conring* (born 1606, d. 1682) opposed Alchemy with much glory and success.

VIII.

Till then no pains were taken to arrange a philosophic system, or to infer general theoretic principles, and fundamental truths from the many chemical facts, discovered partly by accident, partly by necessity, in the various trades, professions and arts, or in alchemical operations. Chemistry had not then existed, but the facts belonging to it had. The establishing of a scientific system of physical Chemistry took place only in the latter half of the seventeenth century.

John Joachim Becher (born 1635, d. 1682) laid the first and extensive ground, upon which *George Ernest Stahl* (born 1660, d. 1734) continued to raise the edifice, endeavouring to collect the principal facts then known into a coherent system, by connecting them by means of general principles. With these men the new epocha of Chemistry begins.

From that time the learned began to reduce this science to more determinate principles and language; they examined the results of experiments with greater accuracy and severity; they considered henceforth *Chemistry* as a *branch of natural Philosophy*, and enlarged thereby its horizon, formerly so much confined by Alchemists; they called the assistance of other kindred sciences to its improvement; the mysterious language was more and more set aside, and Chemistry was not only more philosophically

phically treated, but also rendered more useful to the community.

By laying the basis of a rational Chemistry, this science was enriched with facts, one experiment supported another, and an accidental discovery led to those made by design. The concurrence of several favourable circumstances animated the spirit of inquiry of many great men; their co-operating industry soon brought forth an astonishing multitude of new facts, as also the knowledge of new, till then unknown substances, and raised the science rapidly to greater perfection.

Among the number of men, who since that period have in the present century acquired to themselves lasting fame, by cultivating this science, I can only select here the most celebrated. As of the

GERMANS: Frederic *Hoffman*, John Henry *Pott*, Caspar *Neuman*, John Fred. *Cartheuser*, John Andr. *Cramer*, Christopher Ehregott *Gellert*, John George *Model*, John Gottlieb *Lehmann*, Andr. Sigism. *Marggraf*, John Fred. *Meyer*, John Reinbold *Spielmann*, John Christoph. Polycarp. *Erzleben*, Ignatius de *Born*, Charles Count de *Sickingen*, Charles Wm. *Scheele*, Charles Fred. *Wenzel*.*

* To these must be added the learned *Dr. Gren*, author of the present book, deceased on the 26th November, 1798.—Ed.

Not to offend, I mention none of the German Chemists * now living.

* The translator makes free to add the names of *Klaproth*, who and *Vauquelin* may be reckoned the best analysts; and besides *Crell*, *Hermstaedt*, *Goettling*, *Leonhardi*, *Wiegleb*, *Tromsdorf*, *Westrumb*, *Gmelin*, *Hagen*, *Jaquin*, *Succow*, *Weigel*, *Richter*, *Scherer*, *Gerhard*, *Achard*, *Lowitz*, &c.

DUTCH: Herman. *Boerhaave*, Hieron. David *Gaubius*, John *Ingenhousfs*, Van *Mons*.

FRENCH: The two *Geoffroys*; *Reaumur*; du *Hamel* du *Monceau*; *Hellot*, the two *Rouelles*, Petr. Jos. *Macquer*, *Baumé*, *Sage*, *d'Arcet*, *Guyton de Morveau*, *Lavoisier*, *Berthollet*, *Bosc. d'Antic*, *Bayen*, *Monge*, *Fourcroy*, *Chaptal*, *Prieur Adet*, *Haffenfratz*, *Seguin*, *Vauquelin*.

BRITISH: Stephen *Hales*, Wm. *Lewis*, Jos. *Black*, Henry *Cavendish*, Jos. *Priestley*, Adair *Crawford*, Richard *Kirwan*, Drs. *Pearson*, *Higgins*, *Crichton*, and *Bancroft*, Sir Charles *Blagden*, *Nicholson*, *Hatchet*, etc.

SPANISH: Juan Joseph and Fausto d'*Elhuyar*.

ITALIANS: John Ant. *Scopoli*, Felix *Fontana*, Marfiglio *Landriani*, Tiber. *Cavallo*, Alex. *Volta*, *Lazaro Spallanzani*.

SWEDES: George *Brandt*, John Gottsch. *Wallerius*, Axel Fred. von *Cronstedt*, Swen *Rinman*, H. T. *Scheffer*, Henry *Gahn*, Torbern *Bergman*.

IX.

What principally constituted the basis of the system, set up by *Stahl* (VIII.), were the phenomena which take place in combustion; or the disengaging of fire in combustible bodies.—*Stahl* presupposed in these the existence of a particular substance, which he called *Phlogiston*, and which he considered as the principle of fire or combustion. It was by the assumption of this substance, that the principal tenets of Chemistry were connected.

Stahl was utterly unacquainted with the influence of air on combustion; yet on the further progress in the knowledge of this influence, and on the interesting and important discoveries of gases in general, the former explanation could not but be found insufficient, to put into mutual agreement all the circumstances accompanying this phenomenon. It was observed, that in the combustion of bodies in general, as well as in the calcination of metals in particular, vital air disappears, and besides, that it may be re-produced, merely by making calcined mercury red-hot, whereby this last is at the same time revived in the metallic state. And this discovery furnished the first reason to doubt the existence of *Phlogiston*, as the principle of fire in combustible bodies and metals.

*Lavoisier**,

Lavoisier *, whom I have already named, (VIII.) among the French Chemists of the present age, was the author of this great and total revolution, in the method of explanation till lately adopted in Chemistry, and founded on the *hypothesis* of phlogiston. He has established a new system, which, as it denies the existence of phlogiston, is called the *Antiphlogistic System*; and which in combustion does not place the principle of fire in the combustible body itself, but in the vital air, which is a necessary requisite to combustion, which itself is thereby decomposed, and whose latent fire is disengaged, while the combustible substance absorbs its basis.

* The history of science, on recording his too early death, will never fail to stigmatize those revolutionary murderers, who caused the head of this innocent man to drop, on the 7th of May, 1794, under the axe of the guillotine.

However, what in the records of Chemistry will give immortality to *Lavoisier*'s name, is not so much this *Antiphlogisticism* or rejection of phlogiston, as the discovery of facts of the utmost importance, whereupon his system is established; or whose discovery it occasioned.—The *Sectarism*, from which it arose, must be useful to the science, keep the spirit of inquiry more alive, and lead to a severer scrutiny of the conclusions drawn from experiments.

Yet

Yet whosoever examines the whole, impartially and without predilection, will find that on adopting the antiphlogistic system, there still remain chasms in the explanation of many phenomena, and especially with regard to the extrication of *light*, (in combustion as well as without), its fixation, its developement, and its changes. It is quite in vain to deduce light from a modification of caloric.—This expression, if it does not involve a modifying cause, means nothing at all. But if it be necessary to admit such a cause, modifying the caloric so as to become light; and, if it may be allowed to call this cause *phlogiston*, it is easy to conceive, first that it is possible to reconcile the antiphlogistic system with the adoption of phlogiston, and then that the latter becomes even necessary, in order to explain satisfactorily *all* the circumstances of its various phenomena.

In the sequel I shall explain the fundamental principles of this united system, which might be called *Eclectic*, as well as those of the strictly *antiphlogistic* system.

X.

As a practical science, Chemistry is founded on observations and experiments. On this account, its method of instruction, to be useful, ought not to be merely speculative, but must likewise offer knowledge in matters of fact.—I shall endeavour to display

play the principles of Chemistry taken in its full extent, to deliver them in a coherent order, and to blend the theory with the experiments, whereon it rests, or by which it is confirmed.

CHEMISTRY.

CHAPTER I.

Preliminary Matters.

Elements of Bodies.

§ 1.

EXPERIENCE teaches, that such natural bodies as are the objects of our sensations, are composed of divers *heterogeneous* parts, or of different kinds in various proportions, and this even when they appear to be an *homogeneous* total, or of the same kind.

§ 2.

To separate these heterogeneous simple parts of bodies, or to combine them again in a different way, and to learn what may be their mutual actions into, and their proportions to one another in these combinations, is the purpose of Chemistry.

§ 3.

This *chemical separation* of the *heterogeneous parts* (*partes dissimilares*) of compound or mixed bodies, we distinguish from the *mechanical separation* of their *homogeneous parts* (*partes similes*). The homogeneous parts resemble the

whole, from which they are derived, and differ from it merely as to magnitude, but not as to their nature. They are likewise called *original*, or *primitive masses (molecules)*, and by some, *integrant parts*. The heterogeneous parts, on the contrary, are different in their properties, as well from one another, as from the total, whose parts they are; yet in a proper combination, and in due proportions, they produce a whole, which to us appears to be homogeneous. In this respect they are called *principles*, *constituent parts (partes constituentes)*; (*particules* by the French), and also *radicals*, if they be not themselves a compound.

Illustration of this, by the examples of atmospheric air, glass, cinnabar, water.

§. 4.

If heterogeneous parts are combined in such a manner, that the whole presents itself even as to its minutest parts in the shape of an homogeneous body, or that in the compound they cannot be distinguished from each other by our senses, the body which they thus form is called *mixed*, or *chemically combined*. If the reverse be the case, that is to say, if the body be made up by a mere apposition of distinguishable parts, it is called a *mingled mass*, or *mechanically united*.—This distinction ought to be carefully remembered.

Instances of mingled bodies. The granite, porphyry, blood, wheat flour.

Some-

Sometimes the parts of a mingled body are not distinguishable from each other by the naked eye, and such would be apt to be mistaken for a *mixed body*, did not other circumstances shew the contrary.

§ 5.

Heterogeneous substances, when merely *mingled*, or made up by mere apposition of parts, preserve their former nature and qualities: on the contrary, if they be *mixed*, they then constitute a body with properties totally different from those of its constituent parts.

Examples: A *mingled mass* of sulphur and calx of arsenic, and their *mixture*, or yellow arsenic, which last is a chemical compound produced by sublimation.—A *mingled mass* of mineral alkali and filiceous sand, and their *mixture*, or chemical combination, glass.

Experiment: Blend or mingle accurately together, two parts of fine white quartz-sand with three parts of mineral alkali, that has lost its water of crystallization. The mingled parts will still exhibit their former nature unchanged.—Melt them with the assistance of the blow-pipe into a clear transparent glass, the mineral alkali will no longer shew in this compound its taste nor its solubility in water.

§ 6.

The combination of *heterogeneous* parts, so as to constitute an homogeneous total, is called a *chemical combination*, or simply *mixture*, *composition* (*synthesis*); and the separation of such parts is called *decomposition* (*analysis*). But if *homogeneous*

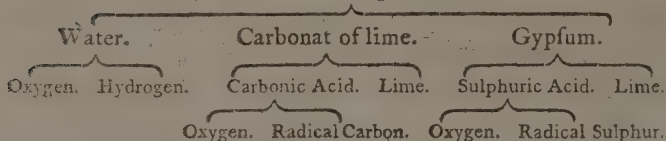
parts are only added together, the process is called *mechanical combination*, or simply *aggregation*, and the product has the name of *aggregate*; *vice versa*, if homogeneous parts are mechanically removed from each other, the term *separation*, or also *division* of the body is made use of. These two last operations do not produce a new body, but a body of an augmented or diminished mass; since then only integrant parts (§ 3) are joined, or separated.

§ 7.

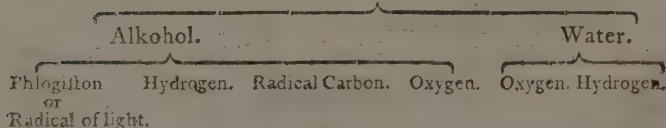
If the constituent parts, obtained from a *mixed*, or from a *mingled* body (§ 4) are still a compound, and did as such pre-exist in the body, and are not altered by the separation, they go by the name of *proximate constituent parts* (*partes proximæ*); and the heterogeneous parts, of which they are composed, have obtained the name of *remote constituent parts* (*partes remotæ*) of that body.

Examples. A. Of Mixed bodies.

1. Common Pump-water.



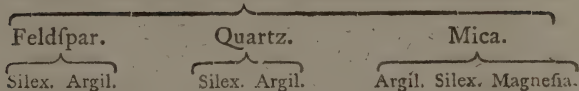
2. Brandy.



B. Of

B. Of a *Mingled* body.

Granite.



§ 8.

The first original substances, of which bodies consist, and which are not themselves compounded of heterogeneous parts, are called *elements, first principles, radicals*. Many substances cannot be farther decomposed by the chemist into constituent heterogeneous parts; but this does not entitle us to rank them among the elements. Though they are as yet *undecomposed*, it does not follow that they are *undecomposable*; as perhaps neither our senses nor our instruments will ever reach those substances which by their nature admit of no sort of decomposition. Of those bodies that are known to us as simple substances, and whose number amounts to *forty*, some may be sensibly exhibited in their simple state uncombined with other matters (*ostensible, producible, simple substances*); others may not, and their existence or presence is only inferred from facts (*unostensible, unproducible simple substances*).

The following is the list of *simple substances*, at present known:

A. Unproducible Simple Substances.

1. <i>Phlogiston</i> , or basis of light	15. Radical of <i>Lead</i>
2. <i>Oxygen</i>	16. ——— <i>Copper</i>
3. <i>Hydrogen</i>	17. ——— <i>Iron</i>
4. <i>Azotic</i>	18. ——— <i>Tin</i>
5. <i>Carbonic</i>	19. ——— <i>Zinc</i>
6. <i>Sulphuric</i>	20. ——— <i>Bismuth</i>
7. <i>Phosphoric</i>	21. ——— <i>Antimony</i>
8. <i>Muriatic</i>	22. ——— <i>Nickel</i>
9. <i>Fluoric</i>	23. ——— <i>Cobalt</i>
10. <i>Boracic</i>	24. ——— <i>Arfenic</i>
11. Radical of <i>Gold</i>	25. ——— <i>Manganese</i>
12. ——— <i>Platina</i>	26. ——— <i>Molybdena</i>
13. ——— <i>Silver</i>	27. ——— <i>Wolfram</i>
14. ——— <i>Mercury</i>	28. ——— <i>Uranium</i>
	29. ——— <i>Titanium</i> .

Radical.

B. Produisible, Ofsensible, Simple Substances.

30. <i>Caloric</i>	36. <i>Argillaceous</i>	} Earth.
31. <i>Siliceous</i>	37. <i>Circon</i>	
32. <i>Calcareous</i>	38. <i>Austral</i>	
33. <i>Magnesian</i>	39. <i>Vegetable</i>	} Alkali.
34. <i>Ponderous</i>	40. <i>Mineral</i>	
35. <i>Strontion</i>		

Earth.

Alkali.

According to Lavoisier's System, the list is,

Unproducible Simple Substances.

1. <i>Oxygène</i>	4. <i>Radical muriatique</i>
2. <i>Hydrogène</i>	5. <i>Radical fluorique</i>
3. <i>Azote</i>	6. <i>Radical boracique</i> .

Produisible

Producible Simple Substances.

7. <i>Calorique</i>	25. <i>Arsenic</i>
8. <i>Lumière</i>	26. <i>Manganèse</i>
9. <i>Carbone</i>	27. <i>Molybdène</i>
10. <i>Soufre</i>	28. <i>Tungstène</i>
11. <i>Phosphore</i>	29. <i>Uranic</i>
<hr/>	
12. <i>Or</i>	30. <i>Titan</i>
<hr/>	
13. <i>Platine</i>	31. <i>Silice</i>
14. <i>Argent</i>	32. <i>Chaux</i>
15. <i>Mercure</i>	33. <i>Magnésie</i>
16. <i>Plomb</i>	34. <i>Baryte</i>
17. <i>Cuivre</i>	35. <i>Terre de Strontion</i>
18. <i>Fer</i>	36. <i>Alumine</i>
19. <i>Etain</i>	37. <i>Terre de Circon</i>
20. <i>Zinc</i>	38. <i>Terre australe</i>
<hr/>	
21. <i>Bismuth</i>	39. <i>Potasse</i>
22. <i>Antimoine</i>	40. <i>Soude.</i>
23. <i>Nickel</i>	
24. <i>Cobalt</i>	

The difference in these two lists, arises from the *Author's* attempt to unite the two systems (IX. Introd.) by adopting a Phlogiston, though in a different way from *Stahl* (§ 182, 189.—194).—Also, from latter discoveries, the *austral earth* should be omitted; and among the metals, the *zellyrium*, and *chrome* added.—Edit.

§ 9.

The impossibility of producing some of these elementary principles arises, no doubt, from their great tendency to unite with other substances, and from the opportunity to meet with them at every separation; so much so, that we know them merely

by the particular ostensible compositions which they form. On this circumstance also depends the cause why we are able to separate, by art, various compounds, but not to reproduce them.

Examples are furnished by *spirit of wine*, *wine* itself, and a vast number of other substances.

§ 10.

In the decomposition of one or more bodies, it frequently happens, that several of their heterogeneous constituent parts unite in different proportions from those they had before, and thus generate a new body, which owes its existence merely to the operation that was performed. Such body is called a *product* (*productum*) in opposition to *educt* (*eductum*), which pre-existed in that body before the decomposition as such a substance, and of the very same properties with which it is obtained. Hence it follows, that every product must be a compound; educts may be simple or compound substances.

An Instance in *carbonic acid gas*, that makes its appearance on mixing a solution of potash with an acid; in *spirit of wine*, on the fermentation of saccharine juices; in the *empyreumatic oil* at the eliquating of tar from pines, firs, and the like.

Mechanical Division and Separation.

§ 11.

The division of bodies into homogeneous parts, and the separation of mingled heterogeneous parts is properly no object of chemistry; it is, however, of great assistance in the chemical examination of bodies. It is performed by *mechanical means*, as they are called, when by an exterior force the cohesion of parts is overcome, and thus the body reduced to pieces. Various instruments are made use of for this purpose, according as the cohesion of the component parts is different,

§ 12.

To the methods of separating homogeneous parts belong, the *breaking* of hard and brittle bodies by the *hammer*, *pounding* and *pulverization* with the *pestle* in metallic mortars; the *pounding* in *stamp-mills*; the *grinding* in mills of various kind; the *trituration* in *trituration-mortars* of agate, glass, serpentine, with a *pestle* of the same materials; the *levigation* and *preparation* on a *grinding-stone*, and a *muller* of some hard stone; the *softening* of hard and brittle stones and glasses, by making them first *red-hot*, and then *quenching* them in cold water.

As to bodies of a tougher nature of the animal and vegetable kingdom, *cutting, planing, grating, rasping* and *stamping*, are means of comminution. As to the ductile metals, the *filing* in a *hand vice*, the *reducing* them to *shavings* on the *turner's lathe*, their *lamination* with the hammer on the *anvil*, or by *rollers* and *stretching-mills*, and *clipping* the obtained laminas with the *shears*, or *graining* and *granulating* like leaden *shot*.

Such pieces as are not small enough, are separated from the finer particles by *sieves* and *strainers*, to be, if necessary, farther attenuated. For this purpose also serves the process of *elutriation*, founded on the experience, that heavier bodies sooner sink in water, than lighter ones.

§ 13.

Blended parts of extraneous matter, and of different specific gravity, are parted in smelting houses by *stamping* and subsequent *washing*; which operations rest on the same principle as *elutriation*.

Solid bodies, when intermingled with liquids, and when of a greater specific gravity, separate by rest; after which the clear liquid may be obtained in a *depurated* state by *decanting*, or may be drawn off by means of a *syphon*. Or else liquids are *strained* (*percolare, filtrare*) to separate the solid bodies

bodies which are mingled with or diffused in them; and to this end several *filtering instruments* are used, as layers of *straw* in casks with perforated bottoms; *conically* twisted *filtering* or *printing paper*, placed in *funnels* or *filtering-baskets*; *linen*, and *tent-cloth*, stretched on a frame (*tenaculum*); loose *hemp*, or *flax*, spread over an expanded net.

Quicksilver is cleaned from filth by being squeezed through a *bag of shammoy-leather*.

What remains in the filtering-instruments is farther freed from the still adhering particles of the fluid, by pouring on it a suitable liquid, commonly water; and this is called *edulcoration* (*edulcorare*); it is also called *lixivation* (*elixivare*), if it be intended to make use of the filtered fluid.

To *clarify* such liquids as do not admit of being filtered, an ingenious process is employed to separate from them the fine floating particles of extraneous matter. For this purpose such substances are added, as in a cold temperature may be dissolved in the liquor, but rise to the surface by coagulating at an increased heat, as the white of eggs, bullock's-blood, &c. By these the impurities are enveloped, and may therefore be *skimmed* off together.

*Primitive Powers, and the Forms of Matter
depending thereon.*

§ 14.

The separation of bodies into heterogeneous parts, as well as their composition from them, cannot be effected by any outward force, which only destroys the accumulation, but not the mixture of bodies.—By the most subtile comminution of mixed bodies we never obtain their constituent, but merely their integrant parts, or original masses (*molecules*). Therefore, if we intend to destroy the combination of heterogeneous parts, we must rather employ those powers which are inherent in corporeal substances, and by the actions of which they combine among themselves. This primitive power, inherent in all matter, by which homogeneous and heterogeneous parts mutually attract each other, becomes also the means of separating them; because the powers of attraction are of different intensity in the various original substances, as will be shewn hereafter.

§ 15.

We know, by experience, that in the corporeal world changes take place in the condition of beings: changes with regard to place and motion.

These we understand by the expressions, *natural events, phenomena*; and the efficient causes of these changes go by the name of *powers*.

§ 16.

On considering the several matters of this visible world more closely, on scrutinizing carefully their actions and effects, and on pursuing the phenomena up to their first causes, we meet at last with a stop at some effects, which it is impossible for us to analyse farther. To account for these, we are obliged to assume *three primitive powers*, essentially different from one another, inherent in the respective matters of our sensible world; and which, in the present state of our knowledge, are regarded as the first innate causes of all the multifarious phenomena among corporeal beings.

§ 17.

These three primitive causes are: *gravitation*, or power of *gravity*; the *power of cohesion*, or *attractive power*; and the *power of expansion*, or *repulsive power*. They differ essentially from each other, and act upon totally different laws on the substances subjected to their influence.

The *power of gravity* is usually considered as not essentially different from the *power of cohesion*; and both are comprehended under the common name of *power of attraction*; yet the proofs of this do not seem to me convincing.

§ 18.

§ 18.

The phenomena that are occasioned by *gravitation*, or the *power of gravity* (*vis gravitatis*), are not objects of chemistry; they belong to the province of physics. But since the two other primitive powers afford the means of chemical analysis and combination, it is necessary to be acquainted with their phenomena.

§ 19.

The *power of cohesion*, (*vis cohesivis, adhaesivis, attractionis*), is that force of matter, whereby its parts are connected in such a way, that they resist upon their removal or separation; in other words, that they diminish the force employed to effect their separation.

§ 20.

The *power of expansion* (*vis expansiva, repulsionis*), is that force of matter, by which its parts resist when it is attempted to bring them nearer together, or whereby they strive to secede from each other.

§ 21.

Hence, by the cohesive force, the particles of matter are making efforts to approach one another, and by the expansive force they are struggling to separate from each other. Both these forces are consequently in *direct opposition*. If both are

5 equally

equally great, or of equal intensity, they naturally do not cause any motion; that is to say, the result of their reciprocal actions is—rest of the parts. It is in this case only that the body fills its space with *continuity*.

§ 22.

We have reasons to suppose, that the essential and specific difference of the principles (§ 3) in this sensible universe is grounded on the different intensity of their primitive, innate powers, which causes the greater or less degree of activity in the various specific original substances.

Kant's Metaphysical Elem. of Nat. Philosophy, p. 100.

§ 23.

On the reciprocal influence of these primary powers, and their respective intensity, particularly depends the *form of aggregation* which we observe in bodies, wherefore we distinguish three species of aggregation: *solid bodies, liquid fluids, and expandible or elastic fluid bodies.*

§ 24.

Solid bodies (corpora solida), (§ 23) are those which, by the greater intensity of the cohesive force acting in their primary masses, present an apparent and considerable resistance, when their parts are removed from the spaces which they occupy.

Yet

Yet the strength of the cohesive power has, even in different solid bodies, manifold gradations with regard to the surfaces of their original masses; and this again gives rise to particular subdivisions, which, however, are so little distinguished by fixed lines, that the different species, which thereby should be determined, rather imperceptibly run into one another.

§ 25.

Thus we distinguish *hard (corpora dura)* from *soft bodies (mollia)*, by the greater or less resistance they exert on the separation of their parts. Here we observe numberless degrees; and we are in absolute want of a scale by which properly to mark their limits. Such solid bodies as admit of their parts being considerably moved upon one another by an external force, without losing their cohesion, are *supple, tenacious, ductile, malleable (ductilia)*; and, on the contrary, *brittle (fragilia)*, if their parts cannot be displaced without being disjoined, or without destroying their cohesion. The increase of the brittleness of bodies attending their increase of density is, doubtless, an evident effect of the repulsive force that now becomes more active.

It is a common, but false conception, that by the distension of tough bodies, for instance, the drawing of wire, lamination of metals, &c. the parts are, in general, removed more asunder. On the contrary, they approach nearer, when by distension they are moved

moved upon one another, as the increase of specific gravity shews on the drawing of wire, or laminating of metals. Hence it follows, that the volume or bulk must, in this case, decrease; and that a drachm of gold drawn into wire, or beaten into leaves, takes up less room than if cast in the form of a ball.

§ 26.

Contractility, which is likewise called *elasticity*, is the effect of the power of cohesion; it is an *attractive elasticity*, and materially different from *expansive elasticity*. It is met with only in solid bodies; it always pre-supposes ductility, and manifests itself only by this, that the parts removed by an outward force struggle to resume their former propinquity, and do really resume it, whenever that force-gives way.

§ 27.

Fluid bodies (corpora fluida) are those whose parts may be moved upon each other by any force, however small. Of these there are two species, essentially different, to be distinguished: *liquid* and *expansible fluids*.

§ 28.

Liquid fluids, or such as are capable of dropping (*corpora liquida*), (§ 23, 27) present themselves to our senses in the form of a coherent aggregate, and assume, when in small masses, a spherical figure; or they form drops, as often as the

mutual attraction of their parts is not disturbed by other bodies. They undoubtedly possess a certain degree of compressibility, and manifest, when compressed, expansive elasticity.

§ 29.

Expansible, or strictly elastic fluids (fluida elastica expansibilia), shew no cohesion of parts observable by our senses; or the attractive power of their parts is destroyed by their repulsive power, possessed of a stronger activity. On account of this superior expansive force, they must necessarily spread out on all sides without bounds, if the gravity of some parts, or the superior attraction of extraneous substances for them, does not prevent it, and set limits to their expansion.

§ 30.

These expansible fluids (§ 29) I subdivide again in a double point of view: first, into *pure expansible*, and *ponderous expansible*; and then into fluids *expansible by their own nature*, and *expansible by communication or derivation*. In the first, the motion of their parts is actuated by no other force than the expansive power, either original or derivative; and they expand from the place where the repelling force begins to be active, in all directions, with equal facility; and it is only the counteracting force of attraction in other primary sub-

substances, that is able to set limits to their expanding infinitely. These pure elastic fluids are also styled *radiant*. Fluids, elastic by themselves, possess originally their expansive elasticity, such as caloric; at least we know, as to the latter, no substance, and our senses offer us none, wherefrom we could derive its power of expansion.

Though, in order to facilitate the geometrical representation of the ideas that occur on explaining the phenomena presented by pure expansible fluids, it is allowable to represent their propagation in the manner of rays; *viz.* to imagine the propagation of their small spherical particles in straight lines; yet there is nothing that can prove the reality of this *atomistical* manner of representing. Like all other bodies, they rather fill their space, even on greatest rarefaction, with continuity; and the appellation of greater rarity, is but an expression to signify their weaker expansive or repulsive force, which decreases in the ratio, as the square of the distances from the place where their activity begins, increases. I therefore no longer admit *discrete* fluids, as they are termed.

§ 31.

The *ponderous expansible fluids* (§ 30) the different kinds of air, for instance, possess all a derivative expansive elasticity. It will be proved, in the sequel, that every one of them consists of a *ponderable basis*, which is not expansible of itself; but such as, by the reciprocal action of its own attracting and repelling forces, would have the aggregation

gation of solidity: and besides, of a *substance expansive by its own nature*, the caloric, by the superior expansive power of which, the original attractive forces of the basis must necessarily disappear. The gravity of their parts prevents them from expanding in the manner of pure elastic fluids.

§ 32.

The ponderous elastic fluids (§ 30, 31) may be farther subdivided into *aeriform*, or *gaseous* (*fluida aeriformia—fluides gazeux*), and into *vaporous*, or *vapours* (*vapores*). The former preserve their elastic form on whatever compression we are able to employ, and at any degree of cold that we are acquainted with; the elasticity of which they were possessed, is therefore, under these circumstances, permanent; and their combination (§ 31) is not destroyed by mechanical compression. The latter, on the contrary, *viz.* the vaporous fluids, lose their form of elastic aggregation in both ways, by compression and by cold; the innate attractive powers of the parts of their basis will again predominate; and these parts, receding from the caloric, unite to form either solid or liquid bodies.

§ 33.

The liquid-fluid bodies, known to us, are not indebted for this form of aggregation to their original innate powers; by these they would, without

exception, rather be solid bodies. Their liquidity is communicated, and it is an effect of the influence exerted by the expansive caloric, as hereafter will be proved more fully by experiments. Hence caloric has, by its expansive force, a share in producing the form of all ponderous expansible, and of all liquid bodies.

Thus water is, under 0 Reaum, a *solid body (ice)*; above 0 till 80° at the common pressure of the atmosphere, a *liquid* (properly *water*); at 80°, and above, again at the same common pressure of the atmosphere, an *elastic fluid, (aqueous vapour, steam)*.

§ 34.

A great many liquid bodies would, in the usual degree of heat which we live in, not at all appear in that form of liquidity, were it not for the pressure of the atmosphere, by which the original attractive forces of the particles are assisted. We certainly should not even know them as such; but by the expansive power of the caloric combined with them, unless overbalanced by that pressure, they would be transformed into expansible fluids,

Without the pressure of the atmosphere, water would, directly at the point of thawing, assume the form of elastic fluidity, and in no way acquire the intermediate state of liquidity.

Experiment to prove this assertion by means of ether, vide Lavoisier Traité Elem. Tom. I. page 9 & seq.

§ 35.

One remarkable phenomenon relative to the power of attraction inherent in matter, is the determined *figure* assumed by its parts, if that force can act upon them freely and unimpeded. Concerning liquid bodies, it is the *formation of drops*, and concerning solid bodies, it is the *crystallization* or *texture*, which in this view deserve our closer consideration.

§ 36.

All liquid bodies assume, as we have already remarked (§ 28) when in small masses, a spherical figure, and form *drops*, provided they do not unite so much with some other body as to spread upon it. Thus, finely divided quicksilver forms globules on wood, on glass, on stone, and similar matters. The same holds good as to water and wine on wood, glass, paper sprinkled with the seed of the common *club-moss* (*lycopodium clavatum*); and all liquid bodies assume the spherical figure, when falling in small masses through the air, with which they do not cohere. A mere inert fluid mass would, in any case, retain the figure it once possessed, and not form drops. If it be not at first shaped in this figure, it will never be endowed with a globular form, unless a motion of its parts takes place.

Thus the very formation of drops demonstrates, that there must exist a cause which produces that effect.

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This cause cannot be gravity, for this, agreeably to experience, is rather an obstacle to the forming of drops; since, by the weight of the particles, larger drops resting on solid bodies are flattened, and the regular spherical form prevented. The smaller the drops are, and the less their weight is, the more perfect is the sphere which they form.

To explain this phenomenon in a satisfactory way, there remains only the power of attraction between the particles of the liquid body; *viz.* if it is supposed that the elementary particles of a corporeal substance reciprocally attract each other with equal force, and that their aptitude for being moved upon one another be great enough to put no impediment to their motion, it follows, by the true principles of mechanics, that the equilibrium of the attractive forces can only take place when the mass has received a globular shape.

§ 37.

The parts of *solid bodies* likewise assume a determined form, and compose groups of a peculiar figure, when suffered to follow, unimpeded and freely, that motion which, by the power of attraction, is produced among them in determined directions. But here this remarkable circumstance interferes, that the particles do not attract each other in all directions with equal force; and hence

smaller groups already formed, as also primitive figures with certain surfaces, exert a stronger attraction than others; thus forming polyedral solids, which are called *crystals*.

§ 38.

In order that solid bodies may form crystals of determined and regular figures, or, in other words, that they may regularly *crystallize*, it is required, 1st. that they be brought into the state of fluidity, in order that their parts may acquire, in a high degree, the capacity of being moved one over the other; and, 2d. that they do again congeal gradually, and without being disturbed; or, what is the same, do gradually pass from the state of fluidity to that of solidity, during which transition their parts join together in determined directions, and form in that manner bodies, if not always of certain fixed outlines, at least of a determined texture.

Under these conditions it may indeed be said of all solid bodies, that they assume a peculiar decided figure, or that they crystallize: and nature shews us this determined form and texture in numberless solid bodies of the mineral kingdom, and in endless varieties, in stones, salts, metals, sulphur, and congealed water; so much so, that the very formation of organic parts may be derived from similar causes.

If

If many fossil bodies do not appear in such regular form and determined texture, we may nevertheless, from their being met with elsewhere, conclude, that on their concretion, only those conditions were wanting on which this phenomenon depends. Art, it must be admitted, cannot imitate nature in the configuration of many bodies, as it does not possess the means of bringing many substances into the requisite state of fluidity.

Examples: In the crystallization of *saltpetre*, *Glauber's* and other *salts*.

Crystallization of various salts in single drops, that may afterwards be viewed by a microscope.

The *silver-tree*, or *arbor Dianæ*—the *lead-tree*—the *tin-tree*.

§ 39.

The first condition necessary to the formation of crystals (§ 38) mobility, and capacity of being easily displaced, is procured, with respect to solid bodies, by fusion, or by solution in a liquid, or by transformation into vapours; or also, lastly, by a very subtile division in a fluid medium.

The second condition, the removing of what has caused the fluidity, in other words, the concretion is effected either by refrigeration or congelation, or by evaporation of the menstruum, or by precipitation, or by repose and subsidence. Yet here the
attrac-

attraction of the coagulating particles must by no means be disturbed or hindered by any kind of motion, such as stirring, shaking, &c. If the transition from liquidity to solidity be too sudden, the particles then have not sufficient time to unite, as suits the attraction of their surfaces, and the form becomes irregular.

Examples: In the formation of crystalline solid bodies, by passing from the fluid to the solid state; 1st. (after preceding liquefaction by cooling) *snow, ice, sulphur, antimony, bismuth*; 2d. (after preceding solution, by evaporating the solvent medium, or by its frigesfaction) the numerous *salt-crystals, realgar*, (by precipitation) the *metallic tree-like crystallizations*; 3d. (after preceding conversion into vapour) the *crystalline sublimates*, and, as they are called, *chemical flowers*; and, 4th. (after preceding fine division in a fluid) the *stalactites*, or drop-stones.

§ 40.

A vast multitude of larger crystals may be mechanically divided into smaller ones, which then, with regard to figure, may, or may not, resemble the greater. The first is the case, when the separation of the larger crystal can be made in a direction parallel to all its surfaces; otherwise they have no resemblance to it, or the *primitive form* is different from the *secondary*. Abbé Haüy has, in many fossils, investigated this subject with great accuracy; and has, from the accumulation of certain

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primi-

primitive forms, according to some fixed laws, very successfully illustrated the manner in which larger crystals are formed out of secondary figures.

According to Haüy, all the primitive forms of crystals, hitherto discovered, may be reduced to six, namely: the *parallelepipedon*; to which belong the cube, the rhomboid, and all solids terminated by six sides, of which two are always parallel; the *regular tetrahedron*; the *regular octahedron*; the *six-sided column*; the *dodecahedron*, with equal and similar trapeziums; and the *dodecahedron*, with isoscelic-triangular surfaces.

The editor would not forego the use of language adopted by chemists and mineralogists; he hopes, therefore, not to be blamed, if, in describing crystals, he frequently uses the term *column*, where rather that of *parallelepipedon*, or *prism*, should be employed.

§ 41.

Not only the parts of certain bodies cohere together, but likewise entire and different bodies, placed in contact; and this cohesion is, among bodies of the same kind, the stronger, in proportion to the closeness and number of points which touch one another: so likewise do bodies of different kinds cohere among themselves. However, the strength of cohesion between various heterogeneous bodies is very different, notwithstanding that the dimensions of the surfaces placed in contact may be the same.

Two polished brass or glass plates cohere together; but they cohere still more if they be moistened with water, or greased.

Experi-

Experiments towards determining the strength of cohesion of metallic or glass plates with water and quicksilver.

Guyton de Morveau had round plates, of equal size and figure, made of various metals. They were of one inch in diameter; and he ascertained the force with which they adhered to quicksilver, upon the surface of which they were suspended. The plate of

Gold	adhered with a force of	446	grains.
Silver	- - - - -	429	—
Tin	- - - - -	418	—
Lead	- - - - -	397	—
Bismuth	- - - - -	372	—
Zinc	- - - - -	294	—
Copper	- - - - -	142	—
Antimony	- - - - -	126	—
Iron	- - - - -	115	—
Cobalt	- - - - -	8	—

It is upon this cohesion of heterogeneous substances, in close contact, that *glueing, cements, mortar, soldering, tinning, silvering, and gilding*, are founded.

§ 42.

If the particles of a fluid mutually attract each other less strongly than they are attracted by a solid body, they will, when in contact, stick to the latter, and make it *wet*, or diffuse themselves upon it; but, if the contrary take place, they will form small globules or drops.

Upon this greater or less strength of cohesion, which the particles of a fluid have among themselves, in opposition to their coherence with any solid body, depends

pends the concave or convex surface of the fluid in a vessel, its flowing or not flowing down the side of a vessel, on being poured out from it, when quite filled, and its brim not turned downwards; and other such incidents, as that of glass globules swimming upon a fluid, and being seemingly repelled from, or drawn towards the edge of the vessel.

The phenomenon of the *capillary tubes* belongs to this place.

§ 43.

As the different heterogeneous bodies do not cohere together with equal force, so do likewise the different heterogeneous primary substances and constituent parts of bodies shew an unequal strength of attraction for each other. We are taught by experience, that two substances of different kinds, which are combined and united into an homogeneous whole, may be separated, if a third substance be added, towards which either of the two exerts a stronger attraction than it had to its former associate.

Experiments : To a solution of chalk in nitric acid add a solution of pot-ash; the chalk will re-assume its original form.

Into a solution of gold pour some naphtha; shake the whole well, and let it again remain at rest: the naphtha will then deprive the solution of all the gold.

Cause *quicksilver*, dissolved in nitric acid, to re-appear by the addition of *brass* or *copper*, or *copper* dissolved in sulphuric acid, by the addition of iron.

§ 44.

Let us then suppose, that to a body, composed of two heterogeneous constituent parts, A and B, a third substance C be added, and that A has a stronger attraction to C than it has to B, with which it was before combined; in this case A and C will naturally unite. If, now, the combination A C has no longer any attraction to B, this latter will of course be excluded from it. Here, therefore, a chemical separation and composition takes place; and it appears from this, that the attractive and repulsive powers inherent in matter, are means to produce chemical separations and compositions, which by mechanical means cannot be effected.

Chemical Affinities.

§ 45.

In chemistry, the action of that power which is naturally inherent in heterogeneous substances, and by virtue of which they unite together in various degrees of intensity, goes by the name of *chemical affinity*, or *elective attraction*; and that substance is supposed to possess a *nearer* or greater affinity with another, which is more strongly attracted by it, than to a third which is less.

§ 46.

On a review of the various phenomena which obtain, when substances of different kinds are combined or separated, we cannot help distinguishing several species of affinities, all which may be brought under *three heads*:

1. The *affinity of composition*, or mixing affinity (*affinitas synthetica*), whereby two or more heterogeneous substances unite, to constitute a new and thoroughly homogeneous whole.

Examples: Water and Salt.

Alkohol and Resin.

Sulphuric Acid and Argil.

Nitric Acid and Potash.

Silver and Sulphur.

Silver and Gold.

Silver, Gold and Copper, &c.

§ 47.

To this first species belongs the *appropriation* (*intermediate affinity*), when two substances of different kinds, that shew to one another no component affinity, do, by the assistance of a third, and together with this last, combine and unite into an homogeneous whole. The *preparing affinity*, so called by some, is as little to be considered as a separate species, as the appropriating affinity.

Examples of appropriation.

Fat Oil, Water, Alkali.

Sulphur, Water, Alkali.

§ 48.

2. The *simple affinity* (*affinitas electiva simplex, analytica cum synthesi simplici*) takes place, when two heterogeneous substances, united to one homogeneous total, are parted by adding a third, which more forcibly attracts either of the two united than they do each other, and the one is by this process separated from the other.

Examples. 1.

Preceding composition.

Refin	Alkohol	}	new composition.
	Water		

2.

Preceding composition.

(Alum)

Argil	Sulphuric Acid	}	new composition.
	Vegetable Alkali		

3.

Preceding composition.

(Soap)

Fat oil	Mineral alkali	}	new composition.
	Sulphuric acid		

(Glauber's salt.)

§ 49.

Hitherto it has in vain been attempted to find out a general law by which these affinities act; for there has not yet been collected a sufficient number

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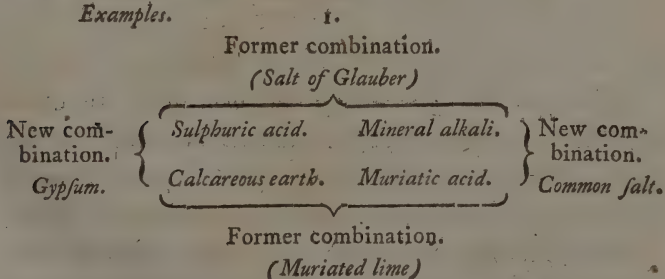
ber of facts to discover that law. Yet towards a general view of the experiments belonging to this subject, we are greatly assisted by the *Tables of simple affinities*, where the various substances are arranged in succession, according to the greater or less elective attraction which each of them has for any particular substance.

These *graduated arrangements* of the simple affinities may be seen in the tables added to the end of the second volume.

§ 50.

3. The third species is the *double affinity*, whereby not one only, but more new combinations are caused, or by which two combined substances are separated on the addition of two others (no matter whether combined or uncombined) by virtue of their respective attractions; and whence, consequently, two new combinations arise, though at times only one separation takes place. This double affinity often causes a decomposition, which the simple affinity is unable to effect.

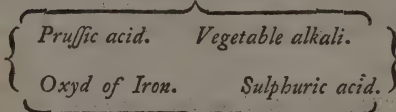
Examples.



2.

Prussiat of Potash.

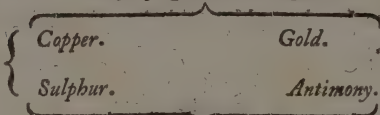
New combination.

Prussian blue.

New combination.

*Sulphat of potash.**(Green vitriol)*

3.

*Alloy of gold and copper.**Sulphuret of Copper.**Alloy of Gold and Antimony.**(Crude Antimony)*

§ 51.

Every chemical decomposition is performed by the assistance of affinities, and two substances united into one homogeneous compound, can never be separated, unless one of them undergoes a new combination.

Chemical Operations and Instruments.

§ 52.

By *chemical operations* or *processes*, we mean the application of proper means to effect a decomposition or composition. Every one of them is grounded on the various degrees of affinities of heterogeneous substances amongst each other, without even excepting the application of fire, whose influence is likewise

likewise (every thing well considered) depending on the affinity of its constituent parts with other substances. Generally speaking, every primary substance may be counted among the *active* chemical instruments, or *chemical agents*.

§ 53.

The considerable changes caused by fire, in the mixture, as well as in the form of so many bodies, is the reason why we cannot avoid placing it among the chief chemical agents, or making frequent use of its application. Whence it is necessary to learn in this place the means of properly maintaining and managing fire; both of which are required, to attain the purposes on account of which fire is applied.

§ 54.

Wood is, on account of its smoke and unequal heat, in few cases only made use of as a fuel, or means of producing fire. *Charcoal* gives the most uniform and best manageable heat, and is most commonly employed. *Pit-coal* affords, indeed, when assisted by a sufficient and strong current of air, a more intense heat than *charcoal*, yet it is in many cases inferior to the latter, as to convenience of application. To obtain a gentle, steady degree of heat, the *fire of a lamp*, maintained by spirit of wine, may serve when *Argand's lamp* cannot be used.

§ 55.

In order to apply fire, to manage and to direct it where it is to act, *furnaces* are convenient, and they are the most necessary and indispensable instruments to chemists. The materials of which they are constructed ought to be sufficiently proof against that degree of heat, which they are intended to be exposed to. Commonly they are built of bricks made of sand and clay, or of cast-iron, or of iron plates, which, the better to be defended against the fire, are *coated* (in the inside) to the thickness of an inch, with Windsor loam. According to *Lewis**, various kinds of fire-proof furnaces, for small experiments, may be prepared from black-lead crucibles.

- * The contrivance is indeed very excellent; as they serve all the purposes of philosophical enquiries. *Lewis* has given a detailed description of them, and plain delineations, in his *Philosophical Commerce of Arts*, 4to. London, 1763, page 1—137, which it is worth the Reader's while to consult.—Excellent *portable furnaces of black lead* are also manufactured at Messrs. *Pugh and Speck's*, Spital-fields, London, and sold at Messrs. *Moser and Jackson's*, Frith-street, Soho.—Ed.

Guyton de Morveau has likewise very successfully employed *Argand's lamps* for chemical operations, as an *æconomical laboratory*. The paper relating to it is inserted in *Nicholson's Chemical Journal*, Vol. II. page 209.—*Frederic Smith*, tin-man, of Gerrard-street, Soho, has accommodated this apparatus for the student at a moderate price.—Ed.

§ 56.

The burning of the fuel is kept up in the furnace either by a natural current of air, which is caused by the fire itself, and such a furnace is called a *wind-furnace* (*furnus anemius*); or it is done by compressed air, conveyed to the furnace, as in *blast-furnaces*.

§ 57.

Every wind-furnace (§ 56) * consists of two essential parts: the *fire-place*, *hearth* (*focus*), or that where the material destined for the fuel is placed; and the *ash-pit* (*cinerarium*) that receives the ashes of the consumed fuel, admits the air through its aperture (*ash-hole*), and is separated from the hearth by the *grate* (*craticula*).

* Plate I. Fig. 1.

§ 58.

If the bodies to be examined be not immediately placed upon the fire, but either on iron bars, or in vessels to be heated by the fire, then a third space, the *laboratory* (*ergastulum*), is formed in the wind-furnace. If by the laboratory the fire-place is thoroughly closed, it must be provided with some *vent-holes*, or *registers* (*spiracula*), to allow access of air.

§ 59.

Such wind-furnaces as are closed by a *vaulted cover* (*cap*, *dome*, or *cupola*) and have, either at top or on the side, a narrow *vent-pipe*, or *chimney* (*caminus*), are called *reverberatory furnaces*, *cuppelling furnaces* (*furni reverberii*) *. Sometimes the fire-place is a part of a separate furnace, from which, however, by the draught of air, the flame of the fuel is forced over, striking upon the hearth of the cuppelling-furnace, which then is to be considered as the laboratory.

* Plate II. Fig. 1 and 2.

§ 60.

The natural current of air, in wind-furnaces, arises from the increased elasticity of that portion of air which is contained in the upper cavity of the fire-place; it being there heated by the fire, and thereby naturally caused to expand. When this air rises by its increased elasticity, the denser and colder air below the grate must, of course, force its way to the hearth, blow the fire, and thus maintain the combustion.

§ 61.

The perfection of a wind-furnace consists, 1, in a good current of air; 2, in keeping the heat together, without losing too great a quantity of it unused; and, 3, in the facility with which the heat may be increased or weakened. The heat, in wind-furnaces,

furnaces, is increased partly by an additional supply of fuel, partly by accelerating the draught of air. The last is effected by opening the door of the ash-pit wider, by shutting that of the fire-place, by opening the registers, and lengthening the chimney by additional vent-pipes, and also by applying the action of the bellows.—By diminishing the quantity or celerity of the current air; hence, by shutting the ash-hole, the registers, and vent-pipes, the heat is diminished, and the action of fire weakened, or thoroughly suppressed.

§ 62.

Blast-furnaces (§ 56) are of a simpler construction than wind-furnaces, and their ash-pit, hearth, and laboratory, are commonly but one and the same part. The *blowing* is most frequently done by *bellows*, which for small experiments are always made of *leather*; and, to act without interruption, should be *double*. At the smelting works, *wooden bellows* are used; but these being *single*, there are always, at the same time, two of them employed, alternately opening and shutting. The *cylinder-bellows* are a discovery of modern times, and exceed the common by many advantages.—*Water-drums*, as they are called, may likewise serve for these purposes.

Of Mr. Baader's *Water-blast*.—He has given a description of it, with five plates. Göttingen. 4to. 1794.

Blast-furnaces, as used in smelting-houses, may be seen in *Jar's Voyages Metallurgiques*, 4to. Lyon, 1774. Vol. III. See Tome I. Plate 1. 2. 3. 4. 6.—Ed.

§ 63.

When the vessels in which bodies are exposed to the action of heat, are not placed in immediate contact with the fire in the wind-furnace, but receive the required degree of heat by another intermediate body, such apparatus is called a *bath* (*balneum*). The proper instrument for this purpose is the *sand-furnace* (*furnus catini*), or a wind-furnace, whose upper aperture is shut by the *sand-pot* (*catinus*). * Sand-pots are cylindrical vessels having an outwardly convex bottom, and made of cast or sheet iron, and at times of baked clay. Glass vessels, however, containing bodies that are to be exposed to heat, are not placed in the pot while empty; but in order that they may be heated uniformly, this last is filled with some other body, into which the vessels are lodged. The matter most commonly employed in this case is dry, finely-sifted sand; and the pot filled with it is called *sand-bath* (*balneum arenæ*) † Of all baths, the sand-bath is the most convenient, and sufficient to apply any degree, from gentle warmth to red-heat. Crucibles (*crucible-bath*) placed between coals, are also used for a sand-bath, instead of sand-pots.

* Plate III. Fig. 1. C.

† Some-

† Sometimes, when a low heat is required, the pot is filled with wood-ashes; as *vice versa* the heat may be increased by mixing the sand with iron filings, or employing simply these latter.—Edit.

§ 64.

If vessels be heated by means of hot water, in which they are immersed, it is called a *water-bath* (*balneum mariæ*) *; but if they be heated merely by the steam of boiling water, it is called *vapour-bath*. Since water, boiling in the open air, is capable of receiving only a determinate degree of heat, it becomes thereby a sure means to impart heat, without danger of exceeding a certain degree.

* For this purpose the sand-pot, or any other vessel filled with water, may be used; even the common still, by sinking into its body holding water, another vessel that contains the substance to be heated.—The water-bath, therefore, requires no particular furnace, or apparatus. (Plate V. Fig. 1. G).—Edit.

They also formerly distinguished four degrees of heat.—That of *evaporation* and *digestion* ending at 50° Fahrenheit; that of *distillation* and *boiling* fixed at 212°; that of *sublimation* at 600°; that of *melting* and *vitrification* at 1600°.—However, there is no certain dependance upon these; mercury and fat oils require a greater heat to boil than water; lead fuses at the 540th degree; ether and ammonia rise by a very gentle heat.—Edit.

§ 65.

Of the various means that serve for chemical inquiry into the nature of bodies, and which are all founded on the affinities and the action of fire, we shall now consider the processes of *solution*, *precipitation*, *fusion*, *volatilization*, *distillation*, and *sublimation*, as on these the chief operations in Chemistry depend.

Solution.

§ 66.

If any substance unite with another of a different kind, or heterogeneous, in such a manner as to make with it a mass entirely homogeneous, in which we are no longer able to distinguish the parts of the one substance from those of the other, we call it *solution*.

§ 67.

Of the two substances, that which seems, by its fluidity or quantity, to be the most active, and to take up the other between its supposed interstices, is called the *solvent medium* (*solvens* or *menstruum*) and the other, which, in this case, appears to be rather in a passive state, is called *solvend*, or the *body to be dissolved* (*solvendum*). This distinction, however, is not supported by truth; on the
contrary,

contrary, both matters are really active. It may nevertheless be kept for convenience of language.

§ 68.

In any solution, not only the cohesion by which the parts of the solvend (§ 67) were united is destroyed, but this last is so united with the menstruum, as to make up together a perfectly homogeneous body; in which, though assisted by the best microscopes, we cannot distinguish the heterogeneous parts from each other. For this reason, among the parts of the specifically different matters, dissolving each other, there must necessarily subsist a reciprocal attraction, which is stronger than the attraction between their respective homogeneous parts. In other words, the affinity of the said parts must act in a stronger way than their respective cohesion.

§ 69.

“ In order that a mutual solution of substances, specifically different, be perfect, it is required, that in it no part of the one substance be found which is not also united with a part of the other, in the same proportion which those substances had to each other before the solution.

“ On the other hand, it is evident, that as long as the parts of any substance continue to be heterogeneous aggregates (§ 3), though in a divided state, a solution of them is as impossible as that of larger masses,

masses. It is likewise obvious, that, supposing the solvent power of the menstruum to remain, the solution must go on, till every part is composed of the solvent as well as of the solvend, in the same proportion in which they were added to each other.

“ Since, therefore, in this case, there can exist no part of the *volume*, or space taken up by the solution, which does not contain a part of the *menstruum*; the latter must entirely fill the space as a *continuum*, or what means the same, no interstices can be left between its parts. Thus also, because there cannot exist any part of the volume of the solution which does not also contain a proportional part of the *dissolved matter*, the solution itself must fill with *continuity*, that is to say, without interstices, all the space occupied by the mixture.

“ But if two substances occupy the same individual space, in such a manner that each of them fills it entirely, they then penetrate each other.—Hence a perfect chemical solution is a penetration of matter; which, no doubt, implies a *division in infinitum*. That we cannot comprehend this last, is owing to the impossibility, we lie under, of comprehending the endless divisibility of a continuum, of whatever kind it be.”

Kant's Metaph. Elem. of Nat. Philos. page 95 seq.

It is, however, strange, that *Kant*, from whom the Author has transcribed this passage, could, by such reasoning,
attempt

attempt to revive the obliterated doctrine of the *continuity of matter*, and the *divisibility of bodies in infinitum*. The absurdity is too glaring to need refutation.— Besides, that doctrine has nothing to do with chemistry; at most, it might have served among the antient *Scholastics* as a disputation exercise for their pupils. The obscurity of the above passage could not be remedied by the translation; it is congenial to all writings of Kant, whose fame more depends on abstruseness than real philosophical merit —Edit.

§ 70.

By the principles of that *system* of natural philosophy which is called *Atomistical*, no solution would be possible. What is called solution would be nothing else than a placing together of the small heterogeneous particles. Only *mingled* bodies, not *mixed* (§ 5) could by that theory exist.

§ 71.

The volume of two bodies that have mutually dissolved each other, is commonly smaller than the sum of their volumes before solution. It rarely happens, that the new mixture or compound fills a larger space than was occupied, before solution, by the heterogeneous substances.—Both these circumstances prove that modification, which the attractive and repulsive powers have been caused to undergo by solution.

Examples :

Examples :

1. Before solution at 60° Fahr.

100 grains of Alkohol, of 0,825 specific grav. fill
a volume = 100.

100 grains of water, of 1,000 specif. grav. fill a
volume = 82,5.

2. After solution at the same temperature.

200 grs. $\left\{ \begin{array}{l} 100 \text{ gr. Alkohol} \\ 100 \text{ gr. Water} \end{array} \right\}$ of 0,93002 specif. grav.
fill a volume = 177,41.

The sum of the two volumes was = 182,5.

Hence the diminution of volume is = 5,09.

§ 72.

Diffolved bodies possess different properties, and prove to be, in their nature, totally different from the single substances of which they consist.

§ 73.

Two bodies cannot dissolve each other, unless one at least be in the fluid form. The ancient chemists, therefore, had already adopted the maxim, *corpora non agunt, nisi fluida*. The sum of attractive powers among the respective homogeneous parts of two solid bodies is greater than their affinity. Hence the former must be diminished by liquefaction.

§ 74.

On this account a distinction is made between solutions in the *humid way* (*via humida*), and those

those in the *dry way* (*via sicca*). In the first, one at least of the dissolving substances is already in the liquid form; but in the latter, these substances must first be brought to the state of fluidity, by melting, before a reciprocal solution can take place.

§ 75.

The solutions of several bodies are attended with noise and frothing, which is called *effervescence*, and is caused by a copious and rapid extrication of aeriform substances. This air, however, did not pre-exist in those bodies in the form of air; but assumes this form at the instant in which it is generated. Nor is the effervescence an argument for the power and violence wherewith the parts of bodies, under reciprocal solution, attract each other.

§ 76.

When a fluid menstruum has taken up as much as it can dissolve of a solid body, it is said to be *saturated*. As the nature of the bodies to be dissolved is various, so, in the very same solvent medium, are the limits of saturation greatly different; and, in most cases, these limits are, respecting the individual substance, greatly varied by the temperature; because the *solvent* assumes to itself, before it is saturated, a greater quantity of the *solvend* in heat than in cold.

§ 77.

We must farther consider, in this place, the difference between a *partial* and a *total solution* of a body. In the first, the whole body is not taken up by the fluid menstruum, but only some of its constituent parts, leaving others behind, to which the solvent has no affinity. This partial solution is likewise called *extraction*, and its product an *extract*. Yet in these extractions, by the assistance of *appropriation*, (§ 47) such constituent parts may be taken up by the solvent medium, as otherwise would not be dissolved by it.

As examples, serve the *extracts* from vegetable substances by water and spirit of wine; the separating of gold from silver by *quartation*.

§ 78.

This extraction is performed in various ways, and the application of this process has received various names. If the substances remain in the menstruum without warming it, it is called *soaking*, or *maceration*; but if the extraction be assisted by a moderate heat, not reaching the point of boiling, it is called *digestion*. Another species of extraction is *infusion*, where the menstruum is poured, when hot, on the body under extraction. This is conveniently used when the body contains easily soluble or volatile parts, that would be lost on applying a heat of longer duration, or by boiling. Lastly,

Lastly, when the menstruum together with the substance, from which an extract is to be made, is heated to boiling, the operation is called *decoction*; and the extract thus obtained a *decoction* (*decoctum, apozema*); in which it is not expected to detain those parts that become volatile by the boiling heat of the solvent.

§ 79.

It is necessary that the vessels wherein a solution of any kind is attempted, be not acted upon by the solvent, and the solution thereby defiled. The most usual vessels employed in small experiments, for solutions in the humid way, are of *glass* variously shaped. Such are *matrasses*, or *cucurbits* (*cucurbitæ*); which, as to their size, are subdivided into *separating*, *common*, *master*, or *large matrasses* (*cucurbitæ separatoriæ, vulgares, magistrales*); and *balloons*, *recipients*, or *receivers*, (*excipula*); besides *phials* (*phialæ*)*, *glass cylinders*, or *jars*, and *flasks*, or *bottles*. Use is also made of *earthen pots* and *pans*, manufactured of common pottery, stone ware, Staffordshire ware, and China ware, or porcelain. When the quantities are great, *metallic kettles*, or *caldrons*, and *pots*, are employed; and in these the choice of the metal depends on the nature of the menstruum.—Solutions in the dry way (§ 74) are performed in melting vessels, of which we shall speak when treating of fusion.

* Plate IV.

§ 80.

The solution is promoted by reducing the solvend to small pieces; also by digestion, by boiling, by shaking, and agitating the mixtures. In solutions that are accompanied with effervescence, the body to be dissolved ought to be conveyed only by degrees, little by little, into the solvent medium.

§ 81.

A particular species of solution is the *solution by means of vapour* (*solutio vaporosa*). To assist either the partial or the total solution of any solid body, the menstruum is in this case, in an air-tight vessel, converted into vapour, and in this state it acts on the substance inclosed. By this management the solvent is rendered more efficacious; because, its vapours finding no means to escape, it is made capable of receiving a stronger degree of heat than in open vessels. This kind of solution is performed in *Papin's digester* (*machina & digester Papini*)*; and those fluid menstrea are employed, by which metals are not dissolved or otherwise affected.

* Plate IV. N.

§ 82.

If, in such solutions, the vapours produced by heat originate from a solid body, the partial or total solution, which is the result of that process, is

is called *cementation*; and the substance, which gives out the vapours, is named *cementing-powder*. With this last the body to be dissolved, divided, or otherwise changed, is put by *layers* (*stratum super stratum*) into the *cementing-pot* (*pyxis cementaria*) made of fire-proof, baked clay; and in that state exposed to heat.

§ 83.

The *deliquation* (*deliquium*) of some concrete salts, which, on imbibing moisture from the air, form with it a liquid solution, cannot be regarded as a separate species of solution. Neither can the solution of metals by quicksilver, or *amalgamation*, be considered as such.

Precipitation.

§ 84.

The recovering, or separation of a body from its solvent, by the addition of a third substance, so that the former re-appear in a solid state, however divided, is called *precipitation*. The substance thus recovered is called a *precipitate*; and the super-added body, that occasioned the precipitation, is called *precipitant*.

Examples. Vide above, § 48.

§ 85.

Precipitations are effected by virtue both of simple and double affinity. In the first case, either the menstruum has a greater affinity with the precipitant than with the body dissolved, and for this reason, uniting with the former, throws out the latter; or *vice versa*, the dissolved body possesses a greater affinity with the precipitant than with its menstruum; and, therefore, parting from the latter, forms with the precipitant a powder insoluble in the solvent medium.

§ 86.

It follows from this, that the precipitates, though obtained from the same solution, may be various; and it is possible to precipitate a body from the very same menstruum in a great variety of forms, accordingly as we choose to employ different precipitants.

§ 87.

Precipitations are also, like the solutions (§ 74) subdivided into *precipitation* in the *humid* and in the *dry* way.

§ 88.

Every precipitation is performed by means of affinity, either simple (§ 48), or double (§ 50); and there are, in the strict sense, no *spontaneous precipitates* (*præcipitationes spontaneæ, spurix*) as they are styled by some.

Fusion.

Fusion.

§ 89.

The action of fire, or, more properly, of caloric, on solid bodies, by which they are caused to pass into the state of fluidity, is called *fusion*; and a body rendered liquid by fire is said to be *in fusion, to flow, to melt*.

§ 90.

From what has been said above (§ 24, 28) of the difference between solid and fluid bodies, it follows, that the active expansive power of the caloric is the principle or true cause of fusion; since, by combining with the solid substance, it diminishes and destroys, in a high degree, the attractive force of its particles.—The fluidity of all liquid bodies, we know at present, is merely derivative, and the effect of the influx of caloric. (§ 33.)

§ 91.

If we attend to the different strength of the attractive power which the particles of substances, specifically different, exert on one side amongst themselves, and on the other towards the caloric, we find no ground to wonder why some bodies require a lower, others a higher, temperature to be fused; and that it is possible to meet with some bodies, which, at any degree of temperature, we hitherto know in our atmosphere, continue in the

liquid state. According to the various degrees of fusibility, bodies are discriminated into *refractory*, or of *difficult fusion*, which require the utmost violence of fire to be melted; and simply *fusible*, or of *easy fusion*, that will flow in less heat; yet the limits between these have not yet been ascertained by any fixed scale,

§ 92.

Some mixtures melt with greater ease than the single substances of which they are composed.

As for instance: the *solder* of the tin-men, Mr. Rose's metallic mixture, (of 2 parts bismuth, 1 lead, and 1 tin) that becomes fluid even in boiling water.

§ 93.

Some bodies cannot be rendered fluid by any degree of heat which we are able to produce.— These are called *infusible*, *apyrrous*, *fire-proof*. Several of them may, however, be fused by adding other bodies, which on account of this property are called *fluxes*. Such addition is called at the smelting works, *dressing of the ores*. It is worth remarking, that sometimes these additions are of themselves infusible.

§ 94.

The true fusion ought not to be confounded with the melting of some salt crystals by heat. The last is caused by the aqueous particles contained in

in them dissolving the salt at an increased heat, which they cannot at a weaker. (§ 76.)

§ 95.

When melted bodies by a circumambient medium of a lower temperature, are deprived of so much caloric that the original attractive forces of the bodies of which they are compounded acquire again the degree of intensity requisite to produce the form of solidity; or when, by this loss of caloric, the native attraction among the surfaces of the primitive molecules becomes again active, they *concrete*, or *congeal*.

§ 96.

All bodies must, in consequence of the explanation given (§ 90) of fusion, assume in fusion a greater volume than that which they had in their former state of solidity. This is in every respect confirmed by experience. The exception which some bodies, as ice, bismuth, antimony, sulphur, seem to make, may be easily explained by the crystallization of their parts on concreting.

§ 97.

Since no solution takes place without liquidity, (§ 73.) fusion becomes one of the most effectual operations for solutions and precipitations in the dry way (§ 74, 87). Fusion is, besides, of importance in separating heterogeneous parts simply

mingled (§ 4, 5) by means of their different degrees of fusibility; as also by the circumstance, that various shapes may be given to bodies by casting them into *moulds*, while in a fluid state.

§ 98.

Fusion is sometimes performed without any vessels at all, and then in small quantities, by the flame of a candle or lamp, *with the assistance of the blow-pipe*; but, in larger quantities, by placing the bodies to be fused amongst the coals in a *melting-furnace*. At other times, the operation is done in vessels, subjected to the requisite heat, in the furnace.

§ 99.

When the *blow-pipe* (*tubus ferruminatorius*)*, made of glass or metal, is employed, the air compressed by the mouth is directed on the flame; and the heat, by that means increased, is communicated to the substance to be fused, which generally rests on a support, in a cavity made in a lump of charcoal. The apparatus by which the air is made to stream through the blow-pipe, by means of double bellows, renders this useful instrument capable of being employed by persons whose weak lungs do not permit them to continue the blowing long, or who are not sufficiently skilled in its management. Lastly, the heat of a lamp-flame may be raised to the highest degree, by conducting
oxygen

oxygen gas (vital air) through the blow-pipe, by means of a peculiar apparatus †.

* Plate I. Fig. 6.

† A description of an apparatus suitable for that purpose, together with a *pocket-laboratory*, is given by *Magellan*, in his Appendix to *Cronstedt's Mineralogy*. Such apparatus was sold by Mr. *Brown*, bookseller, Essex-street, Strand.—As the action of the blow-pipe will be oftener mentioned, it is to be observed here, once for all, that the flame of the candle or lamp urged by it consists of a neat luminous blue cone, surrounded by another of a white and more faint appearance, and that the strongest heat is at the *point of the inner flame*.—Edit.

§ 100.

In smelting-houses, the fusion without vessels is performed in a very simple way, by placing the substances to be fused immediately betwixt burning charcoal in the *melting-furnaces*. In these the fusion is urged by bellows; and they are of various constructions, to suit a variety of purposes. Hence also they have received different denominations,

§ 101.

Other kinds of fusion, especially in small quantities, are performed in vessels of various shape and materials. Their most essential properties are, their being infusible at any degree of heat required

quired for melting the bodies to be fused in them; and, besides, their insolubility in that body when melted.

The most usual melting-vessels are *crucibles* (*crucibula*)*, manufactured of refractory clay and sand; the most perfect of which are made at *Großfallmerode* and *Ellrode* in *Hesse*. Some of them are *larger*, and present, on being cut across, circular outlines; others are *smaller*, called *set-crucibles*, because they are of different sizes, to fit into one another like sets of chip-boxes, and have a triangular top. In some cases, *iron* or *silver crucibles* are employed. Those of *Ips* in Upper Austria, or of *Hafnerzell* near *Passau* (*black-lead crucibles*), consist of black-lead and sand; they are made of very different sizes, and are very durable under every change from heat to cold, but improper for melting many saline substances.

We do not as yet possess melting-vessels that in every respect have the qualities mentioned above.—*Crucibles* made of *platina* would, however, in many cases, remedy this inconvenience.

* Plate I. Fig. 3. 4.—Crucibles, of both the Hessian sort and black-lead, as also *portable furnaces* of black-lead, are manufactured near this metropolis by Messrs. *Pugh* and *Speck*, Booth-street, Spitalfields, and the late Mrs. *Hempel's*, King's-road, Chelsea.—Ed.

§ 102.

For the melting of ores in small quantities for docimastic purposes, *assaying crucibles* (the *probirtuten* of the Germans) * are employed, made of the same materials as the earthen ones. They have, in their inner cavity, the form of a double cone, bellying out in the middle, and contracted at both ends, and a proper stand is provided for them. Another species of these are the *chalice-form crucibles* (*kelch-tutten* of the Germans). The *scorifying tests* (*ansiedscherben* of the Germans) and *capsules*, likewise belong to this place.

* Plate I. Fig. 5.

§ 103.

The melting-vessels are placed amongst live-coals, either in a *simple wind-furnace**, or, if they contain refractory substances, in a *melting-furnace*, properly so called, whose strength of action depends on the strength of the current of air, caused by its peculiar construction; or also on a *forge-hearth*, before the nozzle of the bellows, in which case the effect of blowing, and hence the heat, is increased, by weights laid on the bellows. The larger earthen crucibles must not be heated or cooled too suddenly; nor should they be placed on the bare grate, but on a stand or fragment of a brick; and likewise the cold *blast*, or gust of air streaming from
the

the *bellows*, should not strike them directly while red-hot, or else the cold air, coming in contact, will make them burst.

* Pott has constructed an excellent portable melting-furnace, in imitation of that of *Becher* in his *Tripode Hermetico*, page 32; to which the editor wishes by this note to turn the attention of chemists. It is constructed of wrought-iron, coated in the inside with *raw clay* and *brick-dust*, worked up with bullock's-blood. He increases the current of air, and consequently the intensity of heat, by means of a pipe similar to that delineated Plate I. relating to the wind-furnace, conveying cold air to the ash-pit from without the window of the laboratory. By this furnace Pott fused *Oriental* and *Bohemian garnets*, and even *hyacinths*, in two hours, which could not be fused in porcelain fire continued for several days.— See *Pott's Lithoгеогноsia*, Part II.

§ 104.

The *docimastic*, or *assaying-furnace* (*furnus docimasticus*) is used when small quantities are to be fused under the *muffle*, which is an earthen case, in figure half-cylindrical, open on the front, closed behind, provided with a bottom and side-apertures. The use of the muffle is, to put under it in small vessels, called *assaying-tests**, or *cupels*, such bodies as are to be fused without being secluded from the access of air; but must be prevented from being defiled by coals or ashes.

* Plate II. Fig. 2.—These are not to be confounded with the scorifying-tests. (S. 102.) The *cupels* are small saucers, from 2 to 3 inches broad, made of calcined

cined bones and wood-ashes; the *scorifying-tests* are about half a foot broad, and made of mere elixated wood-ashes.—See Plate II. Fig. 11. M.—Edit.

§ 105.

Fused bodies are either suffered to congeal in the melting-vessels, or they are poured into the cavity of a warmed stone, or in an inverted *metallic cone* (*conus fusorius*), or in *ingots* (*lingo*). In these last the fused metals are suffered to congeal in the shape of roundish oblong masses, called *pigs*, or of *bars*; or else fused bodies are cast into moulds, to receive a particular figure. To the instruments for fusion already mentioned are to be added, *iron-peels*, *stirring-hooks*, *beaked-tongs*, *cupel-tongs*, *common-tongs*, *lifting-tongs*, *pincers*, *tweezers*, *nippers*, &c.

Volatilization.

§ 106.

The transmutation of solid bodies into fluids is not the only change of form produced by caloric; but this principle, if combining in greater proportion, is also capable of reducing many of them into the state of *elastic or expansible fluids*, into *vapours*, and into *gases*. To expose a substance to the influence of caloric for the purpose of converting it into an expansible fluid, into vapour,
or

or gas, is termed *volatilizing*; and those substances are called *volatile* which by heat may be transformed into vapours, or to a species of air.

§ 107.

It is likewise by the expansive power of caloric that all vapours and kinds of gases are formed. Their expansibility is only derivative; and every one of them may be looked upon as a combination of a basis not expansible of itself, with caloric, which is expansible by its own nature.

§ 108.

But there is this difference between the vapours and gases, that the first lose their elastic form by compression, or by cold, and are thus decomposed; while the gases undergo no such change by these causes. Any substance of a lower temperature may again decompose the vapour, by depriving its basis of the caloric. The basis, which is thus parted from the vapour, and on its decomposition becomes again perceptible, is on account of the great volume to which it was before distended, in a state of the most subtile division; and in this state it exists, either in the remaining part of undecomposed vapour, or also in the air, forming *smoke* or *fog*. Yet this is no longer a vapour, and is wrongly called so; on the contrary, it constitutes a solid or liquid substance, in the state of a most minute division.

§ 109.

§ 109.

In the actual formation of vapours the atmospheric air has no share at all; it is rather, by its pressure, an impediment to it, or it is the occasion that a greater quantity of caloric is necessary to reduce, at an equal temperature, a determinate quantity of the basis into the very same elastic form as the air possesses; and, besides, to destroy the attractive powers of the substance, which had been increased by the pressure of the air (§ 34). In a vacuum, therefore, (or space exhausted of air) evaporation is more readily accomplished, and at a lower degree of heat, than when a ponderous elastic fluid presses on the body to be evaporated.

§ 110.

The atmospherical air may, indeed, dissolve the vapour that is forming; however, the formation of a vapour is not a solution of its basis in the air. Hence the distinction made between *real evaporation* and *natural exhalation* is not supported by nature; nor can it be proved. Every exhalation is rather a real evaporation, which at a lower temperature goes on more slowly and in smaller quantity, merely because its basis then requires a longer time before it can receive and absorb so much caloric as is necessary to form with it a fluid, equally elastic as the air.

§ 111.

§ 111.

To the volatile (§ 106.) are opposed the *fixed bodies* (*corpora fixa*) which resist volatilization in the fire, or which do not admit of being converted into elastic fluids by caloric. The efficient cause of this property consists, doubtless, in the greater intensity of the attractive powers of their parts to each other, and in the less affinity they have with caloric. Many substances that are fixed by their own nature, may nevertheless be volatilized by the assistance of other volatile substances, with which they chemically combine and rise together. This is termed *co-volatilization*.

§ 112.

Volatilization is a chemical expedient to separate volatile from fixed bodies, or even to part volatile substances from each other, if their volatility be of unequal degrees. When liquid mixtures are exposed to the action of heat, for the purpose of separating the fluid menstruum from the less volatile, or from a fixed body dissolved in it, the process is called *evaporation*.

§ 113.

Evaporation is accelerated by increasing the heat, by facilitating the exhalation of the vapours already formed, by enlarging the surface of the body to be evaporated, and also by agitating and stirring the liquid.

Distillation.

Distillation.

§ 114.

When the vapours rising in volatilization by fire, which otherwise would disperse in the open air, are directed into a colder place, they lose their elastic form, as they are by that means robbed of their caloric. Their basis then separates, and forms, according to its various nature, either a liquid or a *fixed substance*. In the first case, the process is called *distillation*; in the second, *sublimation*.

§ 115.

It is of little moment to discriminate the *humid* from the *dry* distillation. The matter to be distilled is a liquid in the former, but in the latter it is a solid substance; and in both cases a liquid product is formed by the action of fire. The first has likewise, in consequence of the different purposes intended by it, obtained the particular names of *abstraction*, *cobobation*, *rectification* *.

* *Abstraction* is particularly used when a fluid body is again drawn off from the solid, which it has dissolved; *cobobation*, when a distilled fluid is poured afresh upon a substance of the same kind as that upon which it was distilled, and drawn off again, and this repeatedly, to make it more efficacious; *rectification*, when spirituous parts, coming first over, are separated from the aqueous by distillation.—Analogous to this is *dephlegmation*, or distilling over the aqueous

part, including *concentration*; which, with respect to acids, is frequently done also by evaporation or boiling.—Ed.

Former denominations of certain products obtained by distillation: *spirit, oil, butter, phlegm, caput mortuum*.

§ 116.

By *distilling apparatus* are meant the instruments used in distillation; and they are accordingly, as the heat employed, or the product obtained by this process is different, constructed in various forms, and of various materials. Humid distillations, in which the requisite degree of heat does not surpass that of boiling water, are performed in the *common still (vesica)*, usually made of copper, and in the *distilling-furnace (furnus vesicæ)**. The vapours rise through the *alembic, head, or capital (alembicus, capitulum)*, and pass obliquely into its *neck*. This alembic is either of tinned copper, or of pure tin, and in many cases very conveniently made of stone-ware. Such alembics as are provided with an inside *gutter*, are preferable to the common ones. Concerning these Messrs. *Westrumb* and *Neuenhahn* have proposed some advantageous alterations.

* Plate V. Fig. 1.

Chaptal Elements de Chymie, Tome 3. Sect. 5. Chap. 6.

Art. 1. has made an improvement on the common still, by making its bottom in some manner spherical (*bombè*),

(*bombè*), that the fire may equally strike on all parts, and by making it wider than it is high. By this the surface is increased, and hence the evaporation facilitated. Besides, the sides of the still are upright like a cylinder. He also gives it a very wide neck. The head he employs is of a conical form, whose sides make with the base an angle of 75 degrees; as he found by experience, that the water naturally runs down along the sides of such inclination. A little under the conveying tube of the head there is a small projecting gutter. In this manner no drop of the liquid, condensed in the head, falls back into the still.—Edit.

§ 117.

To decompose the vapours passing through the alembic, to separate and to collect their basis when parted from its caloric, *cooling-utensils* (*refrigeratoria*) have been devised. Either the neck of the alembic joins with the *worm*, in the *cooling-tub* * filled with cold water, or the alembic itself is united to and surrounded by a vessel full of cold water. This last is then called *Black-a-Moor's-head* (*caput Æthiopis*) †.

* Plate V. Fig. 2.

† This last species is inconvenient, as the water grows warm too soon and too often; so that the condensation of the vapours is impeded. The remedy afforded by renewing the water is troublesome; and, if neglected, endangers the spoiling of the product.—See Plate V. Fig. 1. H.

§ 118.

The proper instruments for distilling fluids of easy volatilization are *glass-matresses* (§ 79) with an *alembic* or head of the same materials*. This alembic is always provided with a gutter: in it the vapours, refrigerated by the external air, are decomposed, or deprived of part of their caloric, and converted into a liquid, which passes through its neck into the *receiver* (*excipulum*). The *matresses* are lodged in a sand or water-bath (§ 63, 64).

* Plate IV. Fig. D.

The *pelican* of the ancients. (Plate IV. Fig. F.) *Vases de rencontre* of the French.

§ 119.

The distillation by means of a common still, or *matrafs*, with their heads, (§ 116, 118) has been denominated the *direct* or *ascending distillation* (*destillatio recta per ascensum*), in opposition to the *oblique* by inclination, or *lateral* (*destillatio obliqua, per latus*), and the *downwards acting*, or *descending distillation* (*destillatio per descensum*), which is at present seldom used.

§ 120.

Oblique distillations are performed in *retorts* of *glass*, *potter's-clay*, or *iron*. With this view, the first are placed in a sand-bath; the two latter ones are brought in immediate contact with the

the fire; though this is likewise done with glass-retorts, after they have been armed, or *coated* *. Such retorts as have a hole drilled in their upper convexity, which may be closed by a stopper, are styled *tubulated retorts*. (Plate IV. Fig. B.)

- * Windfor loam, or a mixture of sand and clay, well worked with water and cow's-hair or horse-dung, to the consistence of a paste, is laid upon the vessel in successive thin coatings, the preceding being first suffered to dry before it is covered with a fresh layer. By this the retorts are defended from losing their form by the violence of fire, and from cracking by the sudden variations of heat and cold.—Ed.

§ 121.

In distillations with retorts, instead of receivers, cucurbits or matraffes are employed; and then either the neck of the retort is immediately inserted into their aperture, or the retort is otherwise combined with them, by means of an intermediate vessel, called *adopter* * (*tubus intermedius*). There is no particular cooling-apparatus used in this case. A reverberatory furnace, wherein several large iron or earthen retorts may be placed at once, goes by the name of *galley-furnace*.

- * Adopters differ from the *aludels* used in former times in the sublimation of several substances. They were hollow spheres of stone, or earthen-ware, with a short neck projecting at each end, by means of which one globe might be set upon the other. The upper-

most had no opening at top. The *adopters* are tubes growing narrower at one end, from half a foot to three long, and open at both ends. The aludels were set upright; the adopters are joined in a collateral oblique situation. (Plate IV. Fig. K. L.)—Edit.

Chemists have also made use of the *slugard's-furnace* (*athanor*), by which several operations may be carried on at once in various furnaces, joined together in the building, and the heat kept on for a considerable time without attendance. The contrivance consists in a high tower, containing a quantity of fuel, and from which the fire may be distributed into all those different furnaces. The curious reader will find a full description, with a sufficiently detailed engraving of this apparatus, at the end of *Wiegand's General System of Chemistry*, translated by Dr. Hopson, 4to. Lond. 1789.—Edit.

§ 122.

The junctures of the distilling-vessels are closed with various *lutes* or *cements* (*luta*) accommodated to the nature of the products (*destillata*) thereby obtained. If they be aqueous, spirituous, or oily fluids, a wet bladder, or wheaten-flour-paste spread on slips of paper or linen, are found convenient. The residue of almonds (paste of almonds) from which the oil has been expressed, mixed with water, affords likewise a very good lute. If the substances be acid and corrosive, or if they be such as demand a strong heat to be distilled, lutes made of plaster and water, or of quick-lime and whites of eggs, or of clay and loam, or of
glazier's

glazier's putty, (linseed-oil and whiting worked and beaten up to a thick paste) are required.

§ 123.

If in distilling, together with other substances, there are aeriform fluids or gases produced; in that case, the joints of the distilling-vessels must not be entirely closed, or the gases extricated in the beginning must be first suffered to escape through an hole drilled in the receiver. This purpose is best answered by Mr. *Woulfe's apparatus*, and by the distilling apparatus of Mr. *Lavoisier**.

* A delineation and explanation of this is given Plate VI.

§ 124.

The method of distilling *per descensum* (§ 119)* is at present no longer resorted to by chemists. The extracting of tar from firs, and the separating of quicksilver, after *Born's* manner, may serve as examples.

* An instance of this is the method recommended by *Macquer* for obtaining the oil of lemons, oranges, cloves, nutmegs, &c. He places them between fine linen; and if they be of a dry and hard nature, as the *cloves*, he exposes them to the steam of boiling water. The linen, together with their contents, are then sunk nearly half an inch deep into the orifice of a cylindrical glass, which is placed in a larger vessel holding cold water, reaching to half the height of the former. A hollow lid of copper or iron,

closely fitting by an under rim into the inner aperture of the glass-cylinder, is put on. This capsule is first filled with hot ashes, upon which some pieces of charcoal are afterwards kept burning.—*Macquer's Elem. de Chymie Pratique*, Tome II. Chap. 4. Proc. 4.—Edit.

Pneumatic Apparatus.

§ 125.

The discovery of aeriform fluids has, in modern chemistry, occasioned the necessity of some peculiar instruments, by means of which those substances may, in distillations, (§ 106, 123) solutions, (§ 75) or other operations, be caught, collected, and properly managed. The proper instruments for this are styled the *pneumatic apparatus*.

§ 126.

Any kind of air is specifically lighter than any liquid; and, therefore, if not decomposed by it, rises through it in bubbles. On this principle rests the essential part of the apparatus adapted to such operations. Its principal part is the *pneumatic-trough*, which is a kind of reservoir for the liquid, through which the gas is conveyed, and caused to rise, and is filled either with *water* or with *quick-silver* *. Some inches below its brim an horizontal shelf is fastened, in dimension about half or the third part of the width of the trough, and provided
on

on its foremost edge with a row of holes, into which, from underneath, short-necked funnels are fixed. The trough is filled with water, sufficient to cover the shelf to about the height of an inch. The use of the shelf is to support the receivers, which, being previously filled with water or mercury, are placed invertedly, their open end turned down, upon the above-mentioned holes; through which afterwards the gases, conveyed there and directed by means of the funnels, rise in the form of air-bubbles.

* See Plate V. Fig. 2. and 3.

§ 127.

In some cases the trough must be filled with quicksilver, because water decomposes some kinds of air by absorbing their basis. The price and specific gravity of that metal make it necessary to give to the *quicksilver-trough* smaller dimensions. It is either cut in marble, or made of wood well joined. The late *Karsten* has contrived an apparatus, which, to the advantage of saving room, adds that of great conveniency.

§ 128.

To disengage gases, retorts of glass, either common or tubulated, are employed, and placed in a sand bath, or heated by the fire of a lamp. Earthen or coated glass-retorts are put in the naked fire.

If

If necessary, they are joined with a metallic or glass-conveying pipe*. When, besides the aeriform, other fluids are to be collected, the *middle* or intermediate *bottle* finds its use; and to prevent, after cooling, the rising of the water from the trough into the disengaging-vessels, the *tube of safety* is employed. For the extrication of gases taking place in solutions, for which no external heat is required, the bottle called *disengaging-bottle*, or *proof*†, may be used.

* See Lavoisier's apparatus, Plate VI.

† Plate IV. Fig. G. H.

§ 129.

For receivers, to collect the disengaged airs, various cylinders of glass are used, whether graduated or not, either closed at one end, or open at both; and, in this last case, they are made air-tight by a stopper fitted by grinding. Besides these, glass-bells and common bottles are employed.

The most advantageous manipulations on extricating, collecting, and managing the several gases, are best shewn by actual experiment.

§ 130.

To combine with water, in a commodious way, some gases that are only gradually and slowly absorbed

forbed by it, the *glass-apparatus* of *Parker* is serviceable *.

* Plate V. Fig. 5.—*De Vigne* has invented a new apparatus for impregnating waters; of which is given an exact account, and neatly-engraved plate, in *Tilloch's Philosophical Magazine* for June, 1798.

Sublimation.

§ 131.

When vapours, or bodies, volatilized by heat, condense again by cooling into a solid body, *sublimation* (§ 114) takes place. In many cases, together with the sublimation, distillation is combined.

§ 132.

Most of the distilling-vessels are applicable to sublimation; and the process is conducted in matraffes with their alembics, or in retorts and receivers. For small quantities, common medicine-phials are frequently made use of, and for this purpose set in the sand of a crucible-bath, (§ 83) in such a manner, that the body sublimed adheres to their prominent and cooler part. In particular operations spherical glass-vessels and balloons are employed. The

The subluming parts, or *aludels* *, as they are called, are at present out of use. No peculiar refrigerating-vessels are used in sublimation.

* Plate IV. Fig. K. Consult note to 121.—Ed.

§ 133.

Sublimations in the manner of *Geber*, or *Glauber*, are performed with a free access of air. The adhering of the soot on our chimneys, the making of lamp-black, the gathering of white arsenic in the proper flues (*poison-houses*), and the preparing of zinc-flowers, are various instances of this process.

§ 134.

If the body sublimed present itself in the form of a solid, hard, concrete mass, it is called a *sublimate* in the stricter sense of the word; but it has the appellation of *flowers* (*flores*) if it be of a porous, loose texture, and besides of a pulverulent appearance.

Chemical Instruments.

Balances. Weights, &c.

§ 135.

Besides the implements hitherto mentioned, there are others in use, which may be best explained
I when

when treating of the particular processes. Several others require no description. To this class belong *bottles of glass, or earthen-ware, of various size and figure, and destined to preserve a variety of fluid matters; sugar and powder-glasses, stone and wooden-boxes, and chip-boxes, for solid substances; metallic and glass-funnels, separatory-glasses and funnels* *, *cutting-rings, levers, small glass-syringes, spatulas of wood, ivory, and metal; metallic spoons of different magnitudes, glass-tubes for stirring, and the like.*

* Plate IV. Fig. M. O.

§ 136.

Besides these, some physical instruments are of absolute necessity to the chemist. Among the latter are good *barometers and thermometers, whose various scales ought to be well known; good areometers and hydrostatic balances; an air-pump, with the necessary implements; a pretty large burning-lens; load-stones, or magnets; microscopes; and, lastly, an electric-machine.*

§ 137.

Finally, of all the chemical apparatus, *balances and weights* are the most necessary. The former must be procured of various sizes; and it is obvious that they should be very exact, and very sensible. These properties are more especially requisite in the
docimastic

docimastic-balance, in the use of which careful regard must be had to the sensibility and length of its beams.

Nicholson has very ably treated on the construction, use, and several species of balances, in his *First Principles of Chemistry*, 8vo. Lond. 1796.—Editor.

§ 138.

The chemist cannot dispense with being thoroughly acquainted with the various *weights* and their subdivisions. To compare these with one another, the normal, or *standard-penny parts of the Cologne mark-weight* are very commodious. The German chemists use most commonly the *medicinal weight of Nüremberg*. In *commerce* the *pound* is estimated at sixteen ounces (133898 St. P. pts.); but in *medicine* only at twelve ounces. The *ounce* is divided into eight drachms; the drachm into three scruples; the *scruple* into twenty grains.

The editor was at a loss, in what shape to insert this and the following three sections; whether to reduce them all at once to the English, or to the former French weight, which last is repeatedly mentioned in this work. After some hesitation, he resolved to leave them as they are; because they serve as a comparative statement of the several weights in use, with regard to the German, not much known in this country; and because their comparison with the French is met with almost in every book. He will only add their value

value in English weight, yet neglecting very small and insignificant fractions.

Thus, according to *Krusen's* *Hamburger Contorist*, 71 lb. or grains, English *Troy weight*, are equal to 74 lb. or grains, *German apothecaries weight*;

and

1 ounce of the Nueremberg medicinal weight is = 7 drach. 2 scrup. 9 grains English ditto.

§ 139.

Accounts are also made by the *Cologne mark-weight*, where the *pound* (131072 St. P. pts.) is divided into two marks; the *mark* into sixteen loths, or half-ounces; the *loth* into four quentchens, or drachms; the *quentchen* into four pennies; and the *penny* into 256 normal, or *standard penny-parts*; though likewise in 17 *eschen*.

This division takes its origin from the *Regulation of the Mint* by Emp. *Charles the V.* 1524; and by it all very small weights of gold and silver are ascertained in Germany.

In a gross way, 829 lb. *Cologne* are equal to 1038 lb. *English Troy*;

and

1 mark *Cologne* = 7 ounce. 2 dwt. 4 gr. English *Troy*.

§ 140.

By the French *Troy-weight*, or *poids de marc*, the *pound* (137458 Stand. Pen. pts.) is divided
into

into sixteen ounces; the *ounce* into eight gros, or drachms; the *gros* into three deniers, or scruples: each *denier* into 24 grains. A *grain* is farther divided into 24 *carobes*.

In a gross way, according to *Kruse*, 792 French lb. *poids de marc*, are equal to 1038 English lb. Troy;

and

1 lb. French Troy-weight of 16 ounces is equal to 1 lb.
3 ounce. 15 dwt. 3 gr. English Troy.

With this French weight those of other countries are compared in most books of Natural Philosophy and Chemistry. But as there generally prevailed a great variation in these comparisons, *Tillet* has compared the most exact standard-weights of many European countries with the standard-marc, in the Pile preserved at Paris, and called *Poids de Charlemagne*. He has published the result of his researches in the *Mémoires de l'Académie des Sciences* for the year 1767. His statements may, by the exactness and sensibility of the balance, he used, and by the industry of his exertions be depended on for accuracy.

Of late, quite different weights, as well as measures, have been introduced in France. As it would be too long to explain them here, the reader is referred to *Nicholson's Physical and Chemical Journal*, Vol. I. p. 193, and p. 332, where a table is given for reducing the *unities* of the *metre* or length, *litre* or capacity, and *gramme* or weight, to English *inches*, *gallons*, and *grains*.

Of the *Dutch Troy-weight* the *pound* (137970 St. P. pts.) contains sixteen ounces; the *ounce* 20 engels; the *engel* contains 32 aases.

In a gross way, $787\frac{1}{2}$ Dutch Troy lb. are equal to 1038 English ditto;

and

1 lb. Dutch Troy is = 1 lb. 3 ounce. 16 dw. 7 gr. English Troy.

By the proportions given in these notes, it is easy to reduce the German, French, and Dutch weights to the English, and *vice versa*, by the simple rule of three.

In the *English Troy-weight* the *pound* weighs (104688 St. P. pts.), and is divided into twelve ounces; the *ounce* into twenty penny-weights, marked *dwt.*; the *penny-weight* into 24 grains; the *grain* into twenty mites.

The *pound* of the English *apothecaries* is the same with the English Troy weight; only the subdivisions of the *ounce* are different. This last is by them divided into 8 drachms; the *drachm* into 3 scruples; the *scruple* into 20 grains: making in either subdivision 480 grains, each of equal weight for the ounce. By these medicinal prescriptions are prepared; but the drugs are bought and sold by the common *Avoirdupoise* weight.

The *Avoirdupoise* weight has 16 ounces in the *pound*, and the *ounce* is divided into 16 drachms.

1 lb. *Avoirdupoise* is equal to 14 oz. 11 dwts. $15\frac{1}{2}$ grs. Troy.

§ 141.

Gold and *silver* are commonly weighed by the *mark of Cologne*. When *gold* is weighed, the mark (65536 St. P. pts.) is divided into 24 carats, and the *carat* into 12 grains. When *silver* is weighed, the mark is divided into 16 *loths*, or half-ounces; the *loth* into 18 grains.

The same proportion holds good with any small portion of metal; one ounce, or a drachm, for instance. Hence the expression of *gold of 21 carats* denotes, that in a compounded metal there are 21 parts of pure gold, and 3 parts of another alloyed metal in 24 parts, whatever may be the absolute weight of the compound. In a similar way the expression of *silver of 16 loths* is to be explained.

In England, gold and silver are weighed by the Troy weight, (§ 140) and the *ounce of standard gold* for coinage, &c. consists of 22 carats of fine gold, and 2 of copper.—The *pound of standard silver* is 11 oz. 2 dwts. of fine silver, and 18 dwts. of copper.

§ 142.

The *docimastic*, or assaying weight, is a weight proportionally reduced to small quantities; so that, for instance, one ounce may serve in lieu of a *centener*, or *quintal*, or hundred pounds (marked *cwt.*) The proportional divisions of that ounce will then give pounds, ounces, drachms, grains, &c. In Germany the *docimastic centener*, or *cwt.* is usually
of

of the same weight, as the drachm, or *quentchen* (1024 St. P. pts.) of the Cologne mark-weight.

§ 143.

The quantities of *fluid matters*, whenever exactness is required, which always ought to be most carefully attended to in chemical enquiries, should never be determined by measure, but merely by weight.

The measuring of fluids may, in some few cases, be allowed; but then it should be always mentioned for the information of those that will repeat the experiment, or reason on its results; and the more so, when the same kind of fluid is of various specific gravities, as water or spirit of wine; or when, by their nature, particular accuracy is required. Thus the *London College* have, in their *Pharmacopœia*, wisely distinguished the quantities of fluids by measure, (M) and by weight, (P).—Edit.

Re-agents.

§ 144.

Besides the instruments before treated of, the chemist has occasion for a great variety of materials, as means to perform his examinations of the various bodies. Such substances as enable the chemist to draw conclusions respecting the nature and properties of the bodies to be examined, by means of those

alterations which they suffer themselves, or produce in others, are called *tests*, or *re-agents* (*reagentia*). That we may, by means of them, deduce results to be depended on, they must be procured and employed in the state of utmost purity.

These go likewise by the name of *active instruments*, to which also fire, water, air, &c. belong; and are thus distinguished from the *passive instruments*, viz. furnaces, vessels, mortars, &c. *Chemical agents* is another expression for active instruments.—Edit.

CHAPTER II.

Of the more common, Simple and Compound Substances.

§ 145.

BEFORE we attempt an inquiry into the constituent parts of bodies classed under the three kingdoms of nature, we must first bestow our attention on those substances, which do not belong exclusively to any one kingdom in particular, but are dispersed through them all.

Caloric.

§ 146.

The external cause of the sensation which every body knows by the name of *warmth* or *heat* (*calor*) is what we call *caloric*.

§ 147.

The first and most common phenomenon, which we perceive in bodies that are brought to the particular state, in which they excite in us the sensation of warmth or heat, is the increase of bulk, or dilatation.

§ 148.

We employ this change of volume of certain substances, as a measure to determine the increasing or decreasing quantity of that principle which produces warmth; and on this change of bulk is the construction of *calorimeters*, and *thermometers* founded.

§ 149.

Caloric (§ 146) is an *expansible fluid* (§ 29). The action of the calefying substance on our sensations, and on the thermometer, (from both of which we infer the presence of caloric) does, according to experience, manifest itself on all sides of the body which it issues from, spreading in all directions, but with decreasing intensity. Around the heated body we may, therefore, imagine a sphere of caloric, the expansive power of which decreases in proportion as the square of the distance from the heating point increases.

§ 150.

Caloric is also a *pure expansible fluid* (§ 30). It cannot be proved by any argument, that its particles are acted on by the force of gravity. It is therefore absolutely impossible to ascertain the quantities of caloric by weight, and it must in all respects be considered as an *imponderable substance*.

§ 151.

§ 151.

Caloric is, lastly, a *fluid expansible of itself* (§ 30). We are not acquainted with any substance, neither does one single experiment shew us any, from which we can deduce the expansibility of caloric.

§. 152.

By virtue of these properties caloric should distend in infinitum; and it would really do so, were it not for other substances, which by their attractive force for it, render its power of expansion inactive, and thus set limits to its dilatation.

§ 153.

To explain certain phenomena in a more perspicuous way, it may be allowed to imagine the dilatation of caloric in the manner of *rays*, as if its particles expanded divergingly in straight lines from their origin. Yet this way of representing it is not supported by fact. Caloric, though in the state of the greatest rarefaction, rather fills the space which it occupies in *continuity*; that is, as a *continuum* without interstices. By the greater or less density of caloric, nothing more is understood, than the greater or less manifestation of its activity, or of its expansive power. The intensities, ascertained by its actions on the thermometer, are called its *temperatures*.

§ 154.

For want of proper experience, we are not able to state the degree of celerity, with which pure caloric might expand, if no impediment were put in the way of its expansive power. Yet it cannot well be less than that of light.

§ 155.

It is known by experience, that all bodies heated, but not exposed to a lasting cause of warmth, gradually lose again the excess of temperature which they have over bodies around them; and there are no substances on this globe known, that are capable of preserving a heated body included in them, at a temperature higher than that of the circumambient medium. Hence caloric penetrates all bodies.

§ 156.

The production of warmth in bodies, and the increase of their temperature, is, in the *atomistical theory*, explained by the caloric penetrating into their unoccupied interstices, and pervading these bodies by its increasing quantity. But if this were the case, those supposed empty spaces only would be warm, and the particles of matter themselves would remain cold. For this reason it seems rather, that in this case a chemical penetration takes place, as in solutions (§ 69); with this only difference,
that

that the heated matter is not decomposed and actually dissolved by the caloric.

Kant's Elem. of Nat. Philos. p. 99.

§ 157.

That portion of caloric only is really calorific, or producing warmth, the expansive force of which is active, and is not checked in its expansion by the opposing attractive powers of the matter, which composes the bodies which it warms. It is only this species of caloric that operates upon the sensation, and on the thermometer; and is, for that reason, called *free caloric*. As long as it is free, from its very expansion, it is not detained in the place which it occupied; this only happens when its tendency to expand is so reduced to inactivity by the attractive powers of other substances, that it coheres and forms with them a chemical combination. In this state it is called *unperceivable, latent, fixed caloric*.

§ 158.

Hence the temperature of a body (§ 153.) does not indiscriminately depend on the quantity of caloric which it contains, but principally on that portion of free caloric, which is streaming through, and issuing from it.

§ 159.

When a body is at a higher temperature than another with which it is brought into conjunction,
the

the warmth is propagated from the first to the second, and the colder body deprives the warmer of its excess of heat. The temperature of the one, therefore, is lowered, and that of the other is raised. And this change goes on, till both bodies are brought to the same degree of temperature. It is now said, that the warmth of a body, or of its surrounding medium, keeps the *equilibrium* with another body of the same degree of heat.

§ 160.

The equilibrium of warmth, amongst contiguous bodies, consists in the equal intensity of the streams of free caloric, which they reciprocally impart to each other.

§ 161.

If therefore a body send out, at the very same time, as much free caloric as it receives, *its temperature is lasting*. But if at the same time it receives more than it discharges, and does not fix the free caloric which it receives, then its temperature is raised, or the body *is heated*. And, on the contrary, if it emit more than is communicated to it, it is *refrigerated*. The becoming hot, or being cooled, is consequently nothing else, than the difference of the quantity of free caloric escaping from a body or flowing into it.

§ 162.

The human body contains within itself, as long as it is living, a principle of warmth, in the same manner as the bodies of all other warm-blooded animals. In other words, as long as we live, there is a portion of fixed caloric continually set free from our body. This subject can hereafter only be investigated. If, therefore, some other body, being in contact with us, does at one and the same time impart to us more free caloric than it obtains from us, we call it *warm*, or *hot*; but *vice versa* we call it *cold*, if the quantity of caloric which it receives from us be greater than what it remits to us. *Coldness* is nothing positive, but somewhat of a negative kind, or a privation. We do not know what is absolute cold, or the true zero (0) of the thermometer.

Relative notion of the word *coldness*.

Of the *equilibrium* of animal heat.

§ 163.

As long as two bodies continue to be *perfectly homogeneous* (§ 3.) and at the same time their *temperatures* be *equal*, in this case, equal quantities of those bodies must also contain quantities of free caloric, precisely equal; or the quantities of the latter must, at equal temperatures, be in the same proportion as the volumes of those bodies. When, therefore, two *homogeneous* substances of *different*, or *unequal temperatures*, are either mingled or
mixed

mixed together (§ 4.) the distribution of the caloric of the warmer body among both, must be proportional to their volumes, or their masses; as is also proved by experiment.

§ 164.

On the contrary, when *heterogeneous* bodies (§ 3.) and of *different temperatures* are blended with each other, then the excess of the caloric of the warmer body is not distributed in the proportion of their masses; but unequal quantities of free caloric are required, to effect in equal masses of such bodies an equal change of temperature.

For instance: If 1 lb of *quicksilver* be poured on 1 lb of *water* of a higher temperature, the heat of the whole mass will be greater than the arithmetical mean between their former temperatures.—But if the quicksilver be the hotter body, the new temperature will be lower than the said arithmetical medium.—If, for example, the quicksilver be at 110° Farenh. and the water at 44° , the temperature of the blended fluids will not be raised to 77° , as it should, if the surplus of free caloric were divided among those fluids in the proportion of their quantities. It will be only at 47° .—Let now the pound of quicksilver be heated to 44° , and that of water to 110° , then, on stirring them, the common temperature will be 107° .—Hence if the quicksilver loses by this distribution 63° of its warmth, an equal weight of water gains only 3 from this loss of 63° degrees of heat. On the contrary, if the water loses 3° , the quicksilver gains 63° .

It need not be told, that pains have been taken to estimate on these experiments, that portion of caloric which transmigrates into the air, or into the vessel where the water and quicksilver are blended. As, however, such valuation cannot be made with complete accuracy, the numbers stated above are a mere approximation to truth.

§ 165.

Hence if bodies be of different kinds, it would be wrong to conclude from the equality of their temperature, that the quantities of free caloric contained in them, bear the same proportion to one another as the masses of those bodies.

From the preceding example we may infer, that a certain quantity of free caloric, which might warm water of a given temperature to 1 degree higher, would also warm an equal weight of quicksilver of the same temperature to 21 degrees more; and consequently we may conclude from it, that equal quantities of quicksilver and water, both of equal heat, would contain the absolute quantities of free caloric in the proportion of 1 : 21 ; or as 0,047 : 1,000.

§ 166.

The proportion of the quantities of free caloric, by which heterogeneous bodies of equal temperature and of equal weight are penetrated, is called the *specific* or *comparative warmth*, or heat, and, after Crawford, the *capacity of bodies for heat*. If this proportion be determined with respect to the
same

same volume of bodies, *Wilke* calls it *relative heat*.

§ 167.

This specific heat of bodies is ascertained by the change of temperatures, which they shew, when from being first taken of different degrees of warmth, they are afterwards reduced to a common temperature, either by mixing, in the strict sense, or by mere mingling. *Videlicet*; if the weights of both substances are equal, then their specific warmth, after being brought to a common temperature, will be in the inverse ratio of the changes undergone by their former respective temperatures. If the weights of matters to be mingled or mixed are unequal, in that case their specific heats will be inversely, as the products of the changes in their respective temperatures multiplied by their weights.

Example: 1 lb quicksilver of 110° , blended with 1 lb water of 44° , gives 47° (§ 164); hence the change in the temperature of the quicksilver is $110 - 47 = 63$ degr. and that of water is, $47 - 44 = 3$ deg. In consequence of this statement, the specific heat of quicksilver is to that of water as $3 : 63 = 1 : 21 = \frac{1}{21} : 1$.

§ 168.

Many experiments have been made on this head, and tables of the specific heat of bodies have been made out.

The main point in such experiments is, that bodies should never be mingled or mixed together, whose form is altered, or such as either fix the free, or discharge the fixed caloric (§ 157) during that operation. As this has not been always carefully observed, we may fairly mistrust the numbers given in all these tables. Besides, it is hardly possible to value with accuracy that loss of free caloric, which, in other respects, may happen on blending or mixing these substances.

On this account, I think, *Boerhaave* has not as yet been refuted for having supposed, that in heterogeneous bodies of equal temperatures, the absolute quantities of free caloric, which they respectively contain, are to one another in the ratio of their respective volumes, and therefore inversely as the weights of the bodies to each other.

In the above example, on blending of 1℔ quicksilver of 110° Farenh. and 1℔ water of 44°, the common temperature might turn out to be, instead of 47°, not lower than $48\frac{1}{4}$ ° Farenh. (which may indeed be the fact, if the vapours of the water absorb no heat, or if the heat lost may otherwise be better accounted for) and then, by calculation, the specific heat of the quicksilver would be to that of the water, as $48\frac{1}{4} - 44 : 110 - 48\frac{1}{4} :: 4,25 : 61,75 = 1,00 : 14,52$; and hence very nearly in the inverse ratio of their own respective weights. *Specific Gravity*

Frequently the specific warmth and fixed caloric are mistaken for each other.

The *Calorimeter* of Messrs. *Lavoisier* and *de la Plâce*. (*Traité Elementaire de Chimie*. Pl. 3.)—The observations and experiments made with that instrument do not always shew the specific heat of bodies; but they point out the relative quantities of fixed caloric, which, on certain changes of bodies, is disengaged.

§ 169.

Free caloric, which is transmitted to other bodies, does not always remain free as to its whole quantity, but a portion of it, more or less, becomes fixed, and it is this fixed portion that causes the changes of form which bodies undergo, when exposed to the influx of a greater stream of heat. Solid, liquid, and elastic bodies are thereby dilated; solid bodies turn liquid, and both may by it become elastic. These changes cannot happen, except the attractive powers of matter to the caloric weaken and destroy its expansive force; as again, on the contrary, the power of attraction of other substances is altered by the tendency of the caloric to expand, and by that very means a change in their form is effected.

§ 170.

That portion of free caloric, therefore, which is the cause of the effects already mentioned (§ *preced.*) in bodies, loses its calorific power on our sensation, as well as the effect of its action on the thermometer, and becomes fixed, or imperceptible (§ 157); and this, during all the time that it produces the alteration

tion of form in bodies, or is fettered by their attractive forces.

1. Suppose a mass of pounded *ice*, or *snow*, be so much refrigerated in a vessel, that a thermometer placed therein points to 10° Farenh. Let the vessel be now brought into a warmed chamber, in order to expose the cold mass to a lasting and intenser stream of heat. The quicksilver of the thermometer will in this situation gradually rise to 32° degrees; but here it will remain, though the stream of heat flowing to the ice be of a much higher temperature. Consequently, the temperature of the ice, while melting, rises not higher than to 32° , whatever quantities of warming particles may be conveyed to it; but it melts by degrees, and it is only when it has thoroughly done melting, that the thermometer rises. Thus the stream of free caloric, acting on ice of 32° Farenh. does not raise its temperature above the point of freezing; and its action extends no farther, than to change the form of *solid* into *liquid* water, and the caloric spent on such changes becomes unperceivable and fixed.
2. Mix 1 pound of snow at 32° Farenh. with 1 pound of water at 120° ; the temperature of the mixture will not be elevated to 76° , but continue at 32° .
3. Put some water of 32° Farenh. in which a thermometer is suspended, in an open vessel upon the fire; the thermometer rises successively higher and higher, and reaches at last to 212° . At this moment the water is boiling, and the thermometer continues standing at that degree, as long as it is encompassed by the boiling water, let the current of heat conveyed to the water be ever so great. From this it

follows, that the action of the caloric particles on liquid water, does not raise its temperature above 212° , though their own temperature be higher; but that the flowing caloric, directed to the *liquid water*, becomes in this case fixed, and changes the water into *aqueous vapour*. While this change lasts, the thermometer remains at 212° , the point of boiling.

4. Mingle $8\frac{1}{2}$ of iron-filings at 300° Farenh. with $1\frac{1}{2}$ of water at 212° ; the temperature of the united matters will not reach $290\frac{2}{3}$, but remain at 212° .

§ 171.

Yet *fixed caloric* must be distinguished in a double point of view: into the *adhering*, and into such as is *chemically combined*. The first species of fixation takes place on the mere dilatation of bodies, as also on the fusion of solid bodies, and on their changing into vapours; and the other species on the transformation of a substance into air or gas. In the first case, the mere mechanical compression is sufficient to set the fixed caloric free, and any body of a lower temperature is capable of depriving another substance of it.—But in the second case, neither the one nor the other happens.

§ 172.

That caloric, which on the formation of liquid, and of elastic fluid bodies, is fixed, and becomes imperceptible, must of course again present itself in the character of sensible or free caloric, and cause

an

an increase of temperature, whenever elastic fluid bodies are transformed into liquid or solid ones; or when liquid are changed into solid bodies.—Upon this principle the following laws may be established:

§ 173.

I. *Free Caloric is fixed by bodies, that pass from the form of solidity into that of liquidity.*

This law explains:

1. The fixity of the freezing point at the melting of snow or ice (§ 170, note 1).
2. The experiment of note 2, § 170. One pound of water must be heated above 162° Farenh. in order to melt totally one pound of snow at 32° . If the water be hot above 162° , nothing more than the excess of heat which it has above 162° , is divided among the two pounds of water procured by that way.
3. *Pictet's* reflection of cold, as it is styled.
4. The intense cold, produced by mingling snow and smoking spirit of nitre.
5. The great refrigeration attending the solutions of all crystalline salts.
6. The great cold, caused by the thawing of snow blended with salts.

The greatest possible cold, produced by melting pounded ice or snow, together with salts, takes place with regard to any salt, where a saturated solution of that

salt freezes. For after this the cause of refrigeration no longer exists.

7. The great cold, arising when crystalline salt of Glauber is dissolved in concentrated nitric acid.

§ 174.

II. *The fixed Caloric becomes free, when bodies pass from the state of liquidity into that of solidity; and also when they are brought to a thicker consistence.*

This law is the reverse of the last, and its natural consequence. When, therefore, water freezes, it again gives out that heat by which it was made to liquefy. When the congealing goes on only gradually, it is indeed not possible to perceive, by the sensation and thermometer, that portion of the caloric, which every moment is disengaged in small unperceivable quantities only.—Yet on this very caloric matter, now becoming free, depends the reason,

1. Why water, at the freezing point of the atmosphere, does not freeze on a sudden and entirely.
2. Why water, that freezes in a cold greater than of 32° , does nevertheless retain the temperature of 32° without lowering, till its whole mass be frozen.

By this law is farther explained:

3. Why the quicksilver of a thermometer standing in water, contained in a vessel of a narrow neck, and covered with oil, is raised to 32° , when the water is made to freeze by agitation or stirring; though be-

fore this, during repose, the intensity of its cold was below the point of freezing.

4. Why, for instance, if 1 lb of water at 32° be mixed with 1 lb of snow at 4° , nearly $\frac{1}{3}$ pound of the water congeals, and the whole mass is raised to 32° .
5. Why a saturated warm solution of Glauber's salt, contained in a corked bottle, if grown cold in perfect rest, without crystalizing, gets hot in the very moment of crystalization, if then agitated.
6. Why deliquated Glauber's salt, deliquated Epsom salt, deliquated carbonat of mineral alkali, and burnt alum, produce heat on being mixed with water; whereas these very salts, when in their crystalline state, produce cold with it.
7. Why burnt plaster, and still more so, burnt lime, are heated upon the addition of water.
8. From what cause the strong heat arises on mixing oil of vitriol with calcined magnesian earth.
9. The spontaneous inflammation of oils with concentrated nitric acid.
10. The increase of temperature taking place on mixing vitrollic acid with water, vinegar with water, alcohol with water.
11. The slow cooling of melted tallow, fat, resin, and bees-wax.

§ 175.

III. *Free Caloric is rendered imperceptible, or is fixed, on the passing of liquids into the state of elastic fluidity.*

This law explains :

1. The fixity or unchangeableness of the boiling point in open vessels, whenever there is no alteration in the pressure of the atmosphere on the boiling water (§ 170).
2. The phenomenon mentioned before. (§ 170. note 4).
3. Why uncovered vessels, wherein water is boiling, are not sensibly heated above the point of boiling.
4. Why a linen-thread, if wound tightly around a glass full of water, and closed by a stopper, does not burn, when held over the flame of a burning candle.
5. The refrigeration of rooms, in the summer season, by sprinkling them with water.
6. The artificial making of ice at *Benares* in the East-Indies.
7. The great cold produced by the evaporation of ether, and the freezing of water by that means. (*Franklin's Problem*).
8. The frigorific power, as they term it, of a living man situated in a medium, whose temperature is higher than the warmth of blood.
9. Many phenomena conspicuous on the formation of gas, but which cannot yet be explained in this place.

§ 176.

IV. *Fixed Caloric is set free, on the decomposition of elastic fluids, and on their return to the solid or the liquid form.*

This law is again the reverse of the preceding, and explains :

1. Why a small quantity of water in the state of vapour gives out much more heat than an equal quantity of liquid water of the same temperature.
2. Why the decomposition of every kind of air, or gas, is always accompanied by the extrication of free caloric, or heat.

§ 177.

Thus may the calefaction and refrigeration be effected, merely by the changes which bodies endure with regard to their form.

§ 178.

If there were a cover, impenetrable to free caloric, any hot body confined therein would for ever preserve that higher temperature which it is once possessed of ; because the intensity of its caloric would not be enfeebled by expansion. But there exists no matter or substance that is not penetrated by caloric.

§ 179.

It is, however, known by experience, that various bodies do not transmit the caloric with equal celerity, and that though placed in the same medium, they do not allow a certain substance, which they

hold inclosed, to cool in equal times in an equal number of degrees; notwithstanding that both the temperature and volume are the same.

Application of this observation to various phenomena in common life.

§ 180.

This faculty of bodies, of admitting under equal circumstances, the refrigeration of a heated body contained therein, within a shorter or longer time, is called the *faculty or power of conducting heat*; and such body is said to be a *better, or worse conductor of heat*, as allows the refrigeration to go on quicker or slower. Thus straw, charcoal, wood, ashes, wool, feathers, cotton, are worse conductors of heat than water, stone, metals; and we give also in common language, the name of *warm bodies*, or *bodies preserving warmth*, to the former. The powers to conduct heat, in the various bodies, are to each other inversely, as the times during which other bodies, shut up in them, grow cold.

Illustration by experiments made with cotton, seed of lycodium, quicksilver, concerning their power of conducting heat, &c. by Sir Benjamin Thompson, now Count Rumford.

§ 181.

The greater degree of that faculty which some bodies have of transmitting heat, depends chiefly

on

on their power of fixing the free caloric by a greater or speedier dilatation, fusion, or evaporation.

Light. Phlogiston.

§ 182.

The external cause of the sensation called *Seeing*, is indicated by the expressions *light*, or *matter of light* (*Lux*) ; and that state or condition of bodies by which the sensation of seeing is produced in our organ of sight, is styled *Illumination* or *Brightness* (*Claritas*).

§ 183.

Such bodies as display light of themselves, and are a source or cause producing light, as, for example, the sun and burning bodies, are called *luminous*, or *illuminating bodies*. But such bodies as become visible merely by the light communicated to them by the former, are called *illuminated* or *enlightened bodies* ; in case they produce in us the sensation of seeing.

§ 184.

Bodies which do not prevent the perception, by the sense of sight, of other illuminating or illuminated bodies, when placed in a direct line between the latter and the eye, are called *diaphanous*, *transparent bodies*. To these are opposed the *adiaphanous*,

phanous, untransparent, opaque bodies. But among these last, manifold gradations, of greater or less opacity, take place.

§ 185.

The phenomena belonging to optics prove, that light as a pure elastic fluid (§ 30) spreads about, in all directions, from every illuminating or illuminated point; and that around every point, giving or receiving light, a luminous sphere of undeterminate magnitude may be imagined, where the intensity of the stream of light decreases in proportion to the square of the distance from the luminous point. The representation of light, as if it were a *discrete* fluid distending itself in rays, is doubtless useful, to make the optical phenomena more conspicuous. Yet this by no means prevents us from considering that matter, though rarefied to the utmost, as a *continuum*; and to obtain its greater rarity merely from a diminished activity of its inherent force, by which it acts upon us.

§ 186.

Light is essentially different from caloric. If light were caloric very strongly condensed, or, in other words, if caloric became luminous at a certain degree of intensity, it would naturally follow, that no glimpse of light could take place, except at that high temperature; but this is contradicted by experience. Boiling water gives no light, and the
tem-

temperature of shining phosphorus is far below that of boiling water. But to explain the nature of light by a modification of caloric, without adopting a modifying principle, is to assert the existence of an effect without any existing cause.

§ 187.

Light may as to its expansive power, like caloric, be made inactive by affinity with other matters. It may be fixed, and become a constituent part of other bodies, so as to be unable to make an impression on our organ of sight; which it can only do when it is a free or expansible fluid.

§ 188.

This proposition, by means of which many phenomena in nature may be explained, is confirmed by the experience that we can extricate light from such bodies as by themselves do not produce the luminous state, and this in various ways: by *burning* combustible bodies, by *electricity*, and by *calcification* or heating of many substances, in other respects incombustible.

§ 189.

But from the circumstance, that in all these cases (§ 188), where light is to be displayed in a free state, there always is a certain degree of warmth necessary, or at least co-existent, I am inclined to conclude, that light is not a fluid originally elastic (§ 30); but that its expansibility is derived from caloric,

caloric, and consequently, that light is a compound of a *basis of its own*, and *caloric*.

§ 190.

This doctrine of the composition of light of a peculiar basis and caloric, explains also the difference between the various kinds of *coloured light*; in which we may imagine a difference in the proportion of the basis to the caloric. But there is, undoubtedly, a certain fixed proportion of this basis to the caloric required, in order that a luminous product, observable to our organ of sight, should result from their combination. Nor is there any cause to wonder, how it happens, that the portion of caloric, which by this basis is so modified as to produce light with it, is no longer able to excite heat.

§ 191.

It is this basis of light which ought to be distinguished by a particular name; what I call, with *Leonhardi* and *Richter*: *matter of heat, principle of combustion, or phlogiston*.

§ 192.

The *absorption of light*, as it is called, is therefore a real decomposition of light, where its basis, by the attraction of other substances, is dislodged from the caloric, which then is either made free, or again fixed in some way or other; or, lastly, if combined with a smaller portion of the basis of light, is
reflected

reflected in the form of a differently coloured species of light.

§ 193.

The *extrication of light* from bodies, which before were not luminous (§ 183), is the combination of the basis of light (§ 189), they contain,—with caloric.

§ 194.

The most remarkable instance of the disengaging of light is in *combustion* (§ 188); that is to say, the extrication of both the light and caloric, from bodies in conjunction with and by the decomposition of vital air, and some other species of gases. Bodies qualified for this change are called *combustible* or *inflammable*.

By *this system*, therefore, all combustible bodies are compounds, for all of them contain the *basis of light*, i. e. *phlogiston*. By the *antiphlogistic system* the combustible bodies may likewise be simple substances,

Combustible substances that are simple according to the *antiphlogistic system*, are

Composed, agreeably to the system of phlogiston, of

1. Phosphorus	-	Phlogiston and phosphoric radical.
2. Carbon	-	Phlogiston — carbonic radical.
3. Sulphur	-	Phlogiston — sulphuric radical.
4. Basis of inflammable gas (Hydrogen)	} - -	Phlogiston — hydrogen.
5—23. The 19 metals	} - -	Phlogiston and the respective basis of each metal.

Phenomena

Phenomena of Combustion in atmospheric Air.

§ 195.

Take a cylindrical vessel of thin glass, that may be closed at top air tight, by means of a brass screw and interposed leather, and whose capacity may be measured, into sufficiently small portions, by a graduated scale fixed to it from without.

Put into this vessel, full of atmospheric air, a piece of dry phosphorus (at least $\frac{1}{3}$ grain for every three cubic inches of the vessel's capacity); close it then air-tight; heat it gradually by the flame of a candle, first on the side near the bottom, and afterwards the bottom itself. As soon as the phosphorus has been heated to a certain degree, it takes fire of itself, burning with a flame and thick white smoke; but it soon ceases to burn. Continue heating the vessel repeatedly, and let it cool again. The smoke precipitates in the form of flakes, if the vessel and the air contained in it were thoroughly dry, or else these flakes will melt in the moisture.

After every thing has returned to the former temperature, plunge the mouth of the vessel into water or quicksilver, and open its screw. It will be found that the water rises in it; and hence, that
a portion

a portion of air, which it contained, has disappeared.—The water which has risen shews what quantity of air has been destroyed, if its cubic content be compared with that of the whole vessel. This portion of air thus vanished will, in most cases, be about 0,25 to 0,27 of the whole volume that had been employed of atmospheric air. The water forced up in the vessel is four. The remaining air is as unfit for the burning of phosphorus as of every other combustible matter; animals are also suffocated in that air. We shall hereafter speak again of this remainder of air.

If the vessel, after the phosphorus was inclosed in it, has been weighed before the combustion, and is again after this, when cold, put on the balance, no difference of weight will be observed.

If this experiment be made in a spacious and very dry glass-jar, closed with mercury, and if it be so managed, that the phosphorus swimming on that metal is set on fire by a convex lens, in that case the white flakes, which precipitate from its smoke, and are the *phosphoric acid*, if carefully collected, will be found, on being weighed before they melt, to be heavier than the phosphorus employed; that for each grain of burnt phosphorous $2\frac{1}{2}$ of this concrete phosphoric acid are obtained, and hence that each grain of it has obtained an additional weight of about $1\frac{1}{2}$ grains.

Twelve

Twelve cubic inches (Paris) of atmospheric air are required for the burning of about 1 grain of phosphorus; and this air is reduced in dimension about $1\frac{1}{2}$ cubic inches, or in weight about $1\frac{1}{2}$ grains; in such a manner, that the loss in the weight of air wherein phosphorus burns, exactly corresponds with the increase of weight in the phosphoric acid then generated.

Experiments by burning phosphorus in larger metallic vessels, exactly closed. Other experiments by the burning of a candle.

§ 196.

The phenomena mentioned in these experiments obtain, not only when phosphorus is burnt, but on any combustion whatever similar circumstances occur.

1. Every combustible substance, in order to be inflamed, must be heated to a certain degree; more or less so, according to its particular nature. Thus phosphorus, for example, requires about 30 degr.

Reaum. of heat.

2. Without air no combustion is effected, and it goes on the more briskly the more access of air is granted.

3. In a given quantity of atmospheric air only a certain quantity of the combustible body can be consumed.

consumed. For instance : of a piece of phosphorus no more than about one grain will be burnt in 12 cub. inches of that air, all the rest remains untouched.

4. The atmospheric air, wherein a body is consumed by fire, loses part of its weight, and is rendered unfit for preserving animal life by respiration, and for promoting combustion.

5. The residue of the burnt matter (whether solid, liquid, or elastic fluid) is as much heavier, as the weight of that portion that has disappeared of atmospheric air.

Composition of atmospheric Air.

§ 197.

It is therefore evident, that the *atmospheric air* (which in this place we discriminate from the atmosphere itself) is a compound of two different kinds of air. First, of such as alone is capable of supporting combustion ; which itself is decomposed in the process of combustion ; which alone is proper for the functions of animal respiration ; which at most amounts to about 0,27 parts of the atmospheric air ; and which (for reasons hereafter to be explained) we distinguish by the name *vital air*, or *oxygen gas*.—It is secondly composed of another kind of air, which is unable to maintain combustion,

tion, wherein animals are suffocated; which at least makes up about 0,73 parts of the atmospheric air, and has received the name of *azotic*, and also *nitrogen gas*.

§ 198.

Of these two kinds of gas the atmospheric air is not in all places composed in the very same proportion: nor can it be otherwise, if we consider, that in the atmosphere there are continually, more or less, those processes going on, whereby the vital air is decomposed. But it is no less certain, that the vital air must always be again restored and generated, to prevent the atmospheric air from becoming quite improper to live in, for animals that respire. We shall hereafter, treating on the growth of plants, become acquainted with a means that supplies the atmosphere with vital air.

§ 199.

Before we proceed to the theory of combustion, it is necessary to examine more closely the properties of vital air.

Vital Air, or OXYGEN GAS. Oxygen.

§ 200.

We know at present a great number of bodies, from which we may, by art, produce *vital air*. It
is

is most amply obtained from nitre and the oxyds of manganese, or mercury, if they be ignited.

§ 201.

With this view, fill a small earthen retort with powdered black oxyd, (or native calx of manganese); lute to the orifice of its neck a tin-tube, put the retort amongst charcoal in a wind furnace, placing the mouth of the tube under the funnel of the shelf in the pneumatic trough (§ 126) filled with water, and heat the retort gradually to redness. At first the atmospherical air of the vessels comes over; but upon the manganese beginning to be ignited, vital air is disengaged, manifesting its presence by inflaming a wooden splinter, that in a glimmering state is brought into contact with it. When no more vital air appears, the orifice of the tube is removed out of the water, and the retort suffered to cool.

§ 202.

This species of air, here obtained, is conspicuously different from the common air of the atmosphere. It is somewhat specifically heavier than the last; a Parisian cubic inch of it weighs, according to *Lavoisier*, at 10° Reaum. and 28° barometer's height, 0,50694 grains (French); whereas an equal volume of atmospheric air weighs, in like circumstances, only 0,46005 gr. It has no smell, no taste, and it shews no trace of an acid.

Its most striking and most characteristic mark is that of being fit for the respiration of animals, and the combustion of inflammable substances. An animal confined in a space, filled with this vital air, is not nearly so soon suffocated as when placed in an equally large space of atmospheric air.

A combustible body that would require about four cubic feet of atmospheric air, to be totally burnt, requires for the same effect no more than one cubic foot of this air, or oxygen gas. The intensity of combustion, or the extrication of light and heat, in this gas, by far exceeds that which obtains in atmospheric air. A wax candle burns in it with a greater and more vivid flame, and with a crackling noise; its dying wick is again inflamed by it. A glowing splinter of wood, a glimmering paper is thereby immediately set in the flaming state; tinder, or touch-wood, which otherwise only glimmers, burns in it with a blue flame. Red-hot coals are more rapidly consumed, and burn with greater brightness. A pointed steel watch-spring, whose point has been ignited, is burnt in it with great scintillation. But exceedingly strong and uncommonly brilliant is the flame of phosphorus, burnt in this kind of air.

§ 203.

When phosphorus is burnt in this vital air, and in a similar manner as in the atmospheric (§ 195),
(but

(but taking to 9 cub. inch. of vital air about 4 grains of phosphorus) we observe the same phenomena taking place, as in the process performed with atmospheric air; and that phosphoric acid is produced, which is afterwards dissolved by the water, when suffered to enter the vessel. But it will also appear, that the intensity of heat and light is greater, that more phosphorus is consumed in an equal bulk of this air, and, besides, that this air, if pure, totally disappears. (Usually, however, there is found a small residue of azotic gas).

The phosphoric acid obtained, weighs, even before liquefaction, nay, even after subsequent ignition, more than the phosphorus employed therein. The increase of weight is in exact proportion with the weight of vital air, which has disappeared. Agreeably to *Lavoisier's* accurate statement, 138 $\frac{1}{2}$ cub. inch. (French), or 69,375 grains of vital air are lost in this operation, if 45 grains (French) of phosphorus were fully consumed; or 100 parts of phosphorus destroy by combustion 154 parts of oxygen gas, by weight, and yield 254 parts of concrete phosphoric acid.

§ 204.

The destruction of vital air in the burning of phosphorus inclosed in a quantity of that gas, as well as its reproduction from manganesian oxyd, are sufficient arguments to shew that it cannot be an

elastic fluid originally such (§ 30), but that its form of elasticity is entirely owing to caloric (§ 31). It consists, like every other kind of air, of a peculiar *ponderable*, and not of itself elastic *basis of its own*, and of the *imponderable caloric*, which is chemically combined with this basis, and transforms it into an elastic fluid.

§ 205.

As this peculiar or appropriate basis of oxygen gas ought to be distinguished by a particular denomination, *Lavoisier* has given it the name of *Oxygen*, or *Acidifying Principle*; partly because several combustible bodies are changed into acids by being burnt in it, and partly because it is a constituent part, or rather the principle of all acidity, as will appear from what follows.—Vital air consists therefore of oxygen and caloric, which are both chemically combined into a new total, and for this reason it is denominated *oxygen gas*.

Synonyma: *Vital air*, *dephlogisticated air*, *pure air*, *fire air*,
(*Är vitalis*, *dephlogisticatus*, *purus*).

§ 206.

The *oxygen gas* itself is not contained in the oxyd of manganese and other solid or liquid bodies, by means of which we may procure it; but only its ponderable constituent part, the *radical oxygen*, by the combination of which with caloric, that gas is first generated. By mere red-heat it is not possible to free the manganese oxyd from all its oxygen.

§ 207.

The combustion of phosphorus and other inflammable bodies, either in atmospherical air (§ 195), or in oxygen gas (§ 203), is, in both cases, a decomposition of the oxygen gas, in which process the caloric is deprived of the oxygen, by the combustible substance having a stronger attraction for it.

§ 208.

Oxygen is with us a simple substance (§ 8), since we are unable to decompose it any farther. It is, besides, not exhibitable by itself, or it cannot be separately produced in its simple state; for at the instant that it might become free, it would again unite with the caloric of the surrounding medium, and form oxygen gas. We know it, therefore, in no other way than by its combinations. It exists very generally dispersed in nature, and is a constituent part of the atmospheric air, of water, of all acids, of all metallic calces or oxyds, and of all bodies of the vegetable and animal kingdoms.

Theory of Fire and Combustion.

§ 209.

I take here the word *fire* in the usual sense of common language, and understand by it that light which is combined with free caloric. *Combustion* is

the extrication of fire with and by the decomposition of oxygen gas. We shall keep to the example quoted of phosphorus (§ 195, § 203). On its combustion two new products, the phosphoric acid and fire, arise from phosphorus and oxygen gas.

§ 210.

In order that the theory of combustion be admissible, it must explain every circumstance by which this phenomenon is accompanied, and be in contradiction with none of them. It, besides, must not be inconsistent with any other fixed invariable law of nature.

§ 211.

According to the *antiphlogistic system* (§ IX. Introd) a combustible body is such (§ 194) as is possessed of the power of attracting, in a certain temperature, the oxygen of vital air more strongly than it is attracted by the caloric. Besides, in that system, oxygen gas does not merely consist of oxygen and caloric, but it likewise contains light, in a fixed state (§ 187), as a constituent part.

If, therefore, phosphorus, at the temperature requisite to its inflammation, be brought into oxygen gas, it robs the latter of its oxygen, and makes with it phosphoric acid; whilst the caloric and the basis, or matter of light, previously *latent* in the gas, are restored to liberty; and, combining together, produce

produce the fire which flies off. Thus the oxygen gas is decomposed.

A new body, the phosphoric acid, is now generated; and, because in many cases an acid is produced by the combustion of inflammable matters this circumstance has induced modern chemists to denote the basis of vital air by the words *acidifying principle*, or *oxygen*; not on the ground that it is supposed to be four of itself, but because it forms an acid only when combined with an *acidifiable basis*, as in our experiment with phosphorus. And it is on this account that, in this system, combustion has likewise received the name of *oxygenation*. But in the case (very often occurring) where the combustible matter imbibes oxygen, yet without becoming thereby an acid, the product is called *oxyd* (also denominated *half-acid*), and the process is termed *oxydation*.

Since the combustible substance takes up the ponderable basis of oxygen gas, and since, according to this system, both the caloric and light are imponderable, it is thereby accounted for, why the residue of burnt matters, the phosphoric acid, for instance, acquires an increase of weight equal to that portion of vital air which was decomposed.— If the inflammable substance be saturated with oxygen, it is rendered incapable of decomposing more oxygen gas, and the combustion is ended.

When

When the combustion is performed in atmospheric air, it is then the azotic, either mingled or mixed with the oxygen gas, that prevents these phenomena from going on with the same vivacity as in pure oxygen gas; and likewise, as the azotic gas is not affected or acted on by the inflammable body, it is left as the residue of the atmospheric air.

§ 212.

Hence, by that system, the combustion of phosphorus in oxygen gas is effected by a simple affinity (§ 48), and the principle of fire is not in the combustible body, but in the oxygen gas.

However, from what I have stated of the composition of light, I cannot help thinking, that in combustion a double affinity takes place; and to explain this theory I shall select the example of phosphorus. That substance consists of the basis of light, called by me *phlogiston*, and making a constituent part of all combustible bodies (§ 191) united to a peculiar body, the *phosphoric-radical*. — *Oxygen gas* is a compound of *oxygen* and *caloric* (§ 204, 205).

Now, when phosphorus is heated in this gas, and by this means the force of attraction between the phlogiston and the phosphoric-radical is sufficiently weakened, so that the attractive power between the
radical

radical of phosphorus and the oxygen may prevail, then the act of combustion ensues. The phosphoric basis attracts the oxygen, while the phlogiston of the phosphorus is attracted by the caloric of the oxygen gas. Thus, by virtue of this double affinity, two new compounds, the phosphoric acid and fire, arise from the two former combinations, phosphorus and oxygen gas.

When the radical of phosphorus, and in general of any combustible body, has absorbed so much oxygen, that it is saturated with it, the combustion is arrived at its highest degree; and in the same manner it is ended, at the moment when all the quantity of oxygen gas, capable of being decomposed, is exhausted. By this it is explained, why, in a given volume of oxygen gas, only a certain quantity of phosphorus, and in general of every other combustible matter, can be consumed by fire.

The increase of weight in the residue of the burnt substance is, in this phlogistic, or rather *eclectic system* (§ IX. Introd.), likewise explained by the access of oxygen; and the caloric and basis of light are likewise supposed to be both imponderable. The remaining azotic gas, not being acted upon by the combustible matter, is merely the residue of the atmospheric air.

§ 213.

Those that wish to be impartial, must allow that the light, in the *antiphlogistic system*, acts a part quite superfluous; that it may be thoroughly set aside without impairing the system; that by this system those phenomena cannot be explained, where light issues from combustible bodies without any access of vital air, some instances of which will hereafter be given; that the influence of light upon the growth and thriving of plants, upon the changes of their mixture during vegetation, and upon the alteration in the mixture of many other bodies (of the white silver-calx, for example), is by far too great, to allow oxygen gas to be considered as its only reservoir. Finally, it must be granted (an important point) that the antiphlogistic system does in no way explain the incidents preliminary to the process of combustion; and that it affords no argument to shew why a certain degree of heat is necessary, in order that the combustible body be inflamed.

However, as young students are easily perplexed, by stating, throughout the whole system of chemistry, every explanation variously, according to both theories, I shall henceforth explain each phenomenon merely according to the *strict* antiphlogistic system; especially as a thorough acquaintance with this last, obtained by such a method, will make it
easy

easy to apply afterwards the principles of the *eclectic system*, explained above, to any phenomenon.

§ 214.

It appears by experiment, that combustible bodies are burnt either by mere *glowing* or *ignition*, or accompanied with *flame*. Chemical analysis shews, that all bodies burning with flame are either themselves volatile, or contain volatile constituent parts, capable of being transformed by heat into elastic fluids, and particularly into vapours. The flame of burning bodies is, for this reason, the burning vapour or burning gas arising from such bodies.

§ 215.

Substances, different in the utmost degree, may constitute the flame of bodies under combustion. Even the colour of the flame, so various, may be accounted for by this observation.

Examples of coloured flames:

- Spirit of wine burns with a *blue* flame; the solution of borax in alcohol with a *green*; the solution of the muriat of strontion-earth with a *red*.

§ 216.

When substances are mixed, which by their mutual re-actions disengage a sufficient quantity of caloric, and if some inflammable matter be then present,

present, a *spontaneous inflammation* may take place on the access of atmospheric air.

Such instances are the inflammation of oils by concentrated nitric acid, and of the vitriolic acid by calcined magnesia.

§ 217

Inflammable mixtures may likewise be spontaneously inflamed, if caloric be disengaged either by the gradual action of certain constituent parts upon one another, or on the alteration of their form, occasioned by external causes.—Examples of this are: *Homburg's pyrophorus*; the spontaneous inflammation of pyrites, of hemp, lamp-black, or wool, with hemp-seed oil; of the bran of rye strongly roasted, and wrapt up in a packet; as also torrefied root of succory, saw-dust of mahogany wood, &c.*

* In the year 1781 a frigate took fire in the port of Cronstadt, just as she was preparing to set sail, though no fire had been made in her for several days before. By this Mr. *Georgi*, of the Imperial Academy of Peterburgh, was induced to make a number of experiments to account for that spontaneous inflammation, and of which are those alluded to by the author. Mr. *Georgi's* whole paper is inserted in the French *Journal de Physique* for July 1782.—Mr. *Nicholson* has given a concise and instructive abstract of that paper in his *Principles of Chemistry*, B. II. Sect. 5. Ch. 6.—Edit.

AZOTIC, or Nitrogen Gas.—Azot.

§ 218.

We return to the residue, left, after the combustion of phosphorus, in a confined bulk of atmospheric air (§ 195). This remaining air has not in the least the properties of atmospheric air; it is no longer able to support combustion, or to maintain life by respiration. Animals die in it. Its specific gravity is somewhat less than that of atmospheric air. A Parisian cubic inch of it weighs at 28 inch. of the barometer, and at 10 degr. Reaum. 0,4444 grains (French). We have already distinguished it by the name of *azotic gas*.

Synonyma: Phlogisticated air, corrupted air, mephitic air, nitrogen gas (aër phlogisticatus, vitiatius, mephiticus).

§ 219.

By the analogy of the azotic with other gases, it is obvious that it must be a compound of a ponderable basis and caloric. To the first of these constituent parts we give the name of *azot*. It is not producible by itself alone; and it has never yet been decomposed. Hence it is ranked among the simple substances. It is not only a radical principle of our atmospheric air, but also of many other bodies of the vegetable, and especially of the animal kingdom;

dom; upon which account azotic gas may be obtained from them by various operations. This gas is, besides, met with in the air-bladder of fishes. Lastly, azot is one of the constituent parts of nitric acid, of ammoniac, and probably of crude clay, and some other species of earth or stones.

According to the phlogistic system, *azot* is a compound of *phlogiston*, and the peculiar *substratum*, or *radical principle* of *azôt*.

Eudiometer.

§ 220.

As that property of atmospheric air, by which it is conducive to the maintenance of animal life on breathing, solely depends on the quantity of oxygen gas which it contains; and as, besides, a variety of processes, whereby vital air is decomposed or formed, are carried on in the atmosphere (for which reason the atmosphere cannot every where, and at all times, contain an equal portion of vital air), it of course became interesting to investigate, what might be the proportional quantity of oxygen gas contained in the atmosphere, and hence to learn the fitness of air for respiration, which depends on it.

No sooner were the means of decomposing vital air discovered, than pains were taken to find out a method by which the above purpose might be obtained:

tained. The instrument wherein the oxygen gas, of a given volume of air subjected to examination, may be decomposed, and its quantity measured, is called an *eudiometer*.

Priestley is the inventor of this instrument. For this purpose he proposed the nitrous gas, which hereafter will be more fully attended to. *Scheele* employed the sulphuret of iron; and thus we have become acquainted with several eudiometrical processes, which will be explained in their proper places.

Of all these methods, I think the surest, the most simple, and commodious, to be that which has been already described; namely, to decompose the oxygen gas contained in a definite quantity of atmospheric air by the combustion of phosphorus, and to measure the portion of gas which has disappeared (§ 195). The whole apparatus may be made so small and portable as to serve for a pocket-eudiometer. If the instrument be destined merely for examining atmospheric air, it will be sufficient to apply the scale (§ 195) from the orifice of the cylindrical tube down to but half its length, or its cubic contents; to sketch that scale on a slip of paper, pasted on the outside of the eudiometrical tube, and to varnish it over. This half is divided into *fifty* equal parts, which in this case indicate hundredth parts of the whole capacity of the instrument.

§ 221.

However, though by these eudiometrical experiments the quantity of respirable air in one kind of air may be found, it is, nevertheless, not practicable to ascertain by them the absolute goodness and salubrity of such air with regard to respiration. It would be a good deal more useful, had we any means to discover, with certainty and accuracy, those principles, or constituent parts of the air we breathe, which have a noxious influence on our health and manner of living, and were we thus enabled to combine a *cacometer* with the eudiometer.

Of the vapours and choke-damps of the mines, in the shafts, gangues, and pits.

§ 222.

The burning of a body, a candle for instance, is an unquestionable proof of the presence of oxygen gas in the atmospheric air subjected to examination. We may, therefore, advantageously make use of that test, at least to learn whether the air, for example, of subterraneous caverns, pits, mines, and the like, may be inhaled without danger.

§ 223.

Finally, whether our atmospheric air be simply mingled of azotic and oxygen gases, or whether it be a true *mixture* (meaning thereby a chemical
com-

combination or compound of these two kinds of air) seems to me not yet fully decided.

Carbonic Acid Gas.—Carbonic Radical.

§ 224.

On the burning of charcoal, or a great many other substances, in vital air, another circumstance occurs; namely, the generation of a peculiar kind of gas, which does not take place in the combustion of phosphorus.

When charcoal, well charred, is employed, and the process performed in a glass-bell full of oxygen gas closed with mercury, and the coal, having some touch-paper or phosphorus stuck on, is lighted from without by a lens collecting the sun's rays, it will be found that the elastic fluid under the bell does not disappear, as is the case on the burning of phosphorus, but that a new and peculiar kind of gas is formed. This air is unfit for respiration, as well as for maintaining combustion; but is absorbed by cold water, and still more readily by a solution of caustic alkali and lime-water, which last is rendered turbid by it. Hence, if lime-water be brought under the bell above the surface of the quicksilver by which the gas is confined, the volume of air is diminished; and whatever remains of it is the por-

tion of oxygen gas, which during the combustion had escaped the influence of the coal.

This experiment performed in a different way.

§ 225.

According to *Lavoisier's* accurate statement, 72 parts (by weight) of oxygen gas are in this experiment consumed by 28 parts of charcoal; and both form together a new compound, consisting of 100 parts (by weight) of this kind of gas, which is absorbed by lime-water and caustic alkaline lye.

§ 226.

This gas, thus generated by the burning of charcoal in vital air, is called *carbonic-acid gas*. It is remarkably different from others by its greater specific gravity (a Parisian cubic inch of it weighing 0,68985 French grains); by its unfitness for respiration, and the maintenance of combustion; by its acidity, detecting itself by reddening the tincture of litmus; and by being absorbed by cold water, and (what is done by no gas hitherto treated of) by its making lime-water turbid.

Synonyma: *Fixed air, aerial acid gas, aerial acid, chalky acid gas (aër fixus, gas acidum aëreum, acidum aëreum, gas acidum cretæ)* gas sylvestre, vinosum musti of *Van Helmont*.

§ 227.

§ 227.

Like all other kinds of air, the carbonic-acid gas has for its principles a peculiar ponderable basis and caloric. The first has obtained the name *carbonic acid*. The absorption of this gas by cold water, lime-water, and caustic lye, consists in these liquids taking in within themselves its ponderable basis, while at the same time they disengage its caloric, and consequently the gas is decomposed. Free carbonic acid, at the pressure of air, and at the temperature which we live in, is aeriform. On its extrication, it immediately assumes the aerial state.

§ 228.

Carbonic acid (§ 227) is one of the radicals, or constituent parts of a vast many bodies. It exists in several fossils, and especially in crude calcareous earths, as chalk, common lime-stone, and marble; from which it may be extricated in the form of gas by other acids of superior affinity with calcareous earth; and thus chalk is advantageously employed to produce carbonic-acid gas. This acid may likewise be extricated by fire from bodies containing it, as will be seen hereafter: and it is this same acid which causes the frothing in some acidulous springs, in sparkling wines (*vins mouffeux*) as Champaign, in bottled beer, and at every vinous fermentation. It is, besides, generated by breath-

ing; and the exhaled air never fails to contain some carbonic-acid gas.

§ 229.

The carbonic acid itself is evidently a product from *coal*, or *radical carbon* and *oxygen*; because the carbonic-acid gas, generated when charcoal is burnt in vital air (§ 224), weighs exactly as much as the sum of the weights of the coal (not accounting its ashes) and of the oxygen gas that were consumed in the process. At the temperature requisite to ignition, it attracts and takes into its bulk the oxygen, or base of oxygen gas, and disengages the fire of the latter, *viz.* the caloric combined with light (§ 209).

§ 230.

Carbon, or pure coal (§ 229), is in the antiphlogistic system a simple substance (the earthy and saline particles making its ashes being considered as foreign, and intimately mingled with it). *Coal* is tasteless, insoluble in water, not volatile, infusible, and indestructible in the most vehement fire, if air be excluded. It requires a high temperature in order to decompose oxygen gas; and its affinity with oxygen is so great, that even in a red heat it deprives a vast multitude of other burnt bodies of their oxygen, rendering them again susceptible of ignition;

ignition; whence it is said to *difoxyde* those bodies. This radical abounds in all animal and vegetable bodies, and in their proximate constituent parts (§ 7). It exists also in crude iron, steel, and especially in graphite, or black-lead. From this cause it is that some carbonic acid is formed in the conflagration of all combustible matters, of both the animal and vegetable kingdoms.

According to the *phlogistic system*, carbon is not a simple substance, but a compound of *phlogiston*, and the peculiar *substratum* or basis of carbon, which in the list subjoined to § 8 we have called *carbonic radical*. Hence also, in the opinion of phlogistians, *carbonic-acid* is a compound of this *basis of carbon* and *oxygen*.

§ 231.

When charcoal is burnt in common air, there remains not only the azotic-air, but also the then newly generated carbonic-acid gas. This formation of the latter is the true cause why coal burning in an inclosed space of air, whether atmospherical or of oxygen gas, is extinguished before all the vital air is decomposed. From what has been mentioned before, it is easy to judge of the pernicious effects upon the life and health of men, so frequently caused by the burning of charcoal, or, as is the common expression, by the *vapours of charcoal*, in closed apartments.

Water.—HYDROGEN.—*And Inflammable Air,*
or HYDROGEN GAS.

§ 232.

Water exists in nature in a triple form: as solid water, or *ice*; as a liquid fluid, or *water*, properly so called; and as an elastic fluid, or *aqueous vapour*.

§ 233.

Ice is a transparent, brittle body, more or less regularly crystallized, and melting at 32° Farenheit. Its crystals, if regular, are needle-shaped, crossing one another at angles of 60 degr.

§ 234.

When solid water or ice melts, a considerable quantity of caloric is fixed by it (§ 170); which, if it were at once suddenly discharged from the liquefied water at 32° Farenh. would heat water of the same temperature, and of equal weight, nearly to 163° Farenh. Liquid water, therefore, is to be regarded as a combination of a limited quantity of caloric and ice.

§ 235.

Pure water is an unflammable fluid, without colour, taste, or odour, and certainly capable of being

ing somewhat compressed. As has been already observed, it is merely by the pressure of air that water is retained in the state of liquidity at the temperature above the freezing-point.

§ 236.

At the pressure of the atmosphere of 28 inches of the barometer, water requires an intensity of the caloric expressed by 212° Farenh. in order to boil, and to be converted into an elastic fluid, or *aqueous vapour*. The quantity of caloric fixed by water on its transition into the vaporous state, at the usual pressure of common air, is very considerable.

§ 237.

The aqueous, like every other vapour, loses its elastic form by cooling and compression, and is by them decomposed. Its basis parts from the caloric in a most finely-divided state, and forms *fog*, which should no longer be called vapour.

Hence are explained the formation of *clouds*, of *fog*, *dew*, and *hoar-frost*; the visibility of our breath in winter; the tarnishing, or, as it is termed, the sweating of cold bodies in warm and damp rooms; the sweating of windows, and their freezing in such rooms; the icy incrustations or hoariness of buildings, upon thawing, after frost has continued for some time.

Of the *Hygrometer*.

§ 238.

§ 238.

The atmosphere is never free from aqueous vapour, which, however, does not injure its clearness; it is only the decomposed vapour, or fog, that makes it thick *. These vapours, by the continual changes of pressure and temperature of the atmosphere, are incessantly, by turns, decomposed and regenerated.

* The reason of it is, that it is only the *basis* of the aqueous vapour, *viz.* water, but not the *vapour* itself in *pure elastic state*, which produces moisture.—
Edit.

§ 239.

It is not only by having its temperature lowered beneath the point of congelation that water loses its form of liquid fluidity, but it may likewise become solid by the attractive powers of other matters. In this last case it also gives out part of its fixed caloric, as clearly appears from the *water of crystallization* of salts and earths.

§ 240.

Water is a solvent or menstruum of a vast number of bodies; particularly of salts, and several earths. By means of these salts it likewise becomes a menstruum for other bodies, which cannot be dissolved by water alone.

§ 241.

It is from this fact, that only a small quantity of water perfectly pure is met with in nature. To

the purest waters belong the *atmospherical*, especially *snow* and *rain-water*; and next to these the tasteless *spring* and *pump-water*, the *softer* kinds of which are purer than the *harder*; which last derive their hardness, as it is styled, from dissolved earthy neutral salts. The waters, called *mineral waters*, are, with respect to their predominant contents, subdivided into *Acidulous*, *Chalybeate*, *Alkaline*, *Bitter*, *Vitriolic*, *Cement-water*, and *Salt brine-springs*; to the last of which the *Sea-water* belongs.

§ 242.

To procure pure water, distillation is the only effectual means we have. It is necessary that this distillation should be performed, in vessels which do not themselves contaminate the *distilled water*.—Pure water is not subject to any kind of putrefaction, provided it do not happen to be in contact with organic bodies.

Guyton de Morveau recommends a cheaper and more expeditious way to obtain pure water. *Annales de Chimie* Tome XXIV. p. 317. He collects rain-water, which by its nature is only defiled by sulphat of lime taken up from the plaster of the chimneys, tiles, and other pointings of the ridges of the roofs (in France).—Which to disengage, he filters it first, and drops into it a solution of barytes, prepared after the manner of *Vauquelin's* (vid. § 343. n.); until after the precipitation has subsided, the last drop exhibits no alteration of transparency. By the addition of water impregnated

pregnated with carbonic acid, (which however must not be in excess) the precipitation may be suddenly effected.—*Ed.*

§ 243.

The very old opinion that water might be transmuted into earth, which in latter times has been endeavoured to be proved by the growth of plants in simple water, and by its earthy sediment on repeated distillations from glass vessels, is at present completely done away*.

- * Some plants, even of the most succulent kind, and in the hottest climates, as the *Agave*, *Cactus*, *Aloe*, *Cacalia*, grow on the driest ground *without water*.—The residuary matters originated from the distillatory vessels, or were held in solution by the water employed.—*Edit.*

§ 244.

Contrary to the ancient idea, water is not a simple substance, but it may be decomposed or resolved into heterogeneous principles, and be again composed of them.

§ 245.

Take a coated tube made of hard glass, put into the middle of its cavity 274 French grains of iron wire, rolled in a spiral form, lute to its upper orifice the neck of a small glass retort, containing *nearly two ounces* of water, and place this last on a sand bath.—Cause then the middle part of the
tube,

tube, where the wire is lodged, to pass somewhat inclined through a pan of coals, and lute to its lower end the middle bottle (§ 128.) standing in cold water, and from which the conveying pipe (§ 128.) issues, having its other extremity carried under the funnel of the pneumatic trough.—These things being prepared, the middle of the glass tube is heated to redness, but gradually, while the water in the retort is made to boil, and its vapours thus forced to pass through the red-hot wire.

By this process, a quantity of a peculiar kind of air, inflammable, and extremely light, is generated.—If there be no defect in the operation, about 416 Paris cubic inches of this inflammable air, weighing 15 French grains will be obtained, after the atmospherical air has been subtracted. The iron is changed in the tube, being now friable and brittle, or converted into an oxyd (§ 211.) and it weighs 85 grains more than before the operation. The water collected in the intermediate bottle, after the whole quantity is distilled over, falls 100 grains short of what has been employed.

If the computation of the quantities be disregarded, the inflammable air may likewise be prepared in a surer way, by placing in the middle of a gun-barrel some iron wire twisted spirally; by luting to its higher aperture a glass retort filled with water; by making then the middle part of the iron
tube

tube red hot, and directing its lower end under the funnel of the pneumatic trough.

§ 246.

The inflammable air hereby obtained, is, for reasons that will soon appear, denominated *Hydrogen gas*.

This kind of air is the lightest of all gases that we know of. A Parisian cubic inch of it weighs at 10° Reamur, and 28 inches of the barometer 0,03539 French grains, and a cubic foot weighs 61,15 grains. It possesses a peculiar disagreeable smell; is not respirable, and extinguishes a light immersed within it; but it is inflammable, and may be set on fire by an ignited body, if vital or common air find access to it. In this manner it burns with a flame at the orifice of a bottle, descending quicker into the vessel the wider its aperture is.

Hence if this gas be mixed with about three parts of atmospherical air (by bulk), the inflammation caused at the mouth of the flask by a lighted candle, spreads in one moment throughout its whole capacity, and a strong explosion takes place:—still stronger, if one part of oxygen gas be mixed with two parts (by measure) of inflammable air. The safest way of making this experiment is in a bottle of gum-elastic.—These mixtures may also be made
to

to catch fire by an electric spark. Water does not imbibe nor alter hydrogen gas.

§ 247.

In the process by which this gas is generated (§ 245.) the increase of weight of the remaining iron, added to the weight of the obtained inflammable air, exactly corresponds to the weight of water which has disappeared. The natural consequence of this agreement is, that this part of the water must have been spent, partly on the alteration of the iron; partly on the formation of hydrogen gas. The changes which the metal had undergone are exactly the same with those that take place when it is burnt in vital air; hence *oxygen* must be one of the constituent parts of water, and the other is the *ponderable basis of the inflammable air*, thus produced.

By a farther inference, therefore, water must again be generated by combining inflammable air with oxygen; and the fact supports this conclusion. It is on this account, that this basis of inflammable air, being the radical of water, has obtained the name of *Hydrogen*.—Consequently water is a compound of *Hydrogen* and *Oxygen*; and agreeably to the last quoted, and other experiments, consists of 0,15 of the former, and of 0,85 of the latter.

§ 248.

The rationale of the process, quoted from § 245, is then the following. In a red heat, iron deprives water of its oxygen, and is thereby reduced to the state of an imperfect calx of iron, whilst the hydrogen of the water combines with the caloric, and forms hydrogen gas.

§ 249.

This is confirmed by a variation in the foregoing experiment (§ 245). If instead of iron, 28 grains (French) of charcoal, well charred and grossly powdered, are introduced into the tube, 524 Parisian cubic inches of gas will be obtained, not reckoning the atmospheric air of the vessel; and after the end of the experiment, the coal will be found to have disappeared, leaving only a small portion of ashes.—The volume of air obtained consists of 144 cubic inches of *carbonic-acid gas*, separable from the mass by lime-water or caustic lye, and of 380 cubic inches of *hydrogen gas*. The weight of the first is nearly 100 grains; and of the second, $13\frac{7}{10}$ grains. The water collected in the intermediate vessel is $85\frac{7}{10}$ grains less than the quantity used for the experiment.

As in this instance $85\frac{7}{10}$ grains of water disappear, and 100 grains of carbonic acid are formed; and farther, as the last cannot be generated but by the oxygen,

oxygen, and as 28 parts of carbon require for that purpose 72 parts of oxygen (§ 225), it follows, that the $85\frac{7}{10}$ grains of water lost, must have transferred 72 grains of oxygen to the coal; and that the remaining $13\frac{7}{10}$ grains must have formed the ponderable basis of the inflammable gas, or must have been the hydrogen, *viz.* the radical principle of water.—All this agrees again pretty nearly with the above proportion of 85 parts of oxygen to 15 of hydrogen.

§ 250.

In this experiment, therefore, the carbon, assisted by a red heat, robs the water of its oxygen, forming with it the carbonic acid, which flies off in the state of carbonic acid gas; while the other radical of water, the hydrogen, is set at liberty, and uniting with the caloric, escapes in the elastic form, or as hydrogen gas.

§ 251.

The evidence of this conclusion, drawn from analytical experiments, is fully completed by synthesis, or the reproduction of water, by combining the basis of oxygen gas with the basis of hydrogen gas.—If with this intention both kinds of air, in the proportion of 15 parts of hydrogen—to 85 of oxygen gas, are set on fire in a close vessel, both gases are destroyed, and water is again generated, amounting to 100 parts by weight. To perform this combustion with proper conveniency,

some particular kinds of apparatus, called *gazometers*, have been contrived.—That proposed by Mr. *Van Marum* * is the most simple and commodious.

* The *Philosophical Magazine*, Vol. II. for October 1798, page 85, contains a description of it; to which is added, a most beautiful copper-plate engraving, executed by the masterly hand of Mr. *Lowry*. It is much preferable to Lavoisier's very complicated gazometer.—Ed.

§ 252.

The theory of combustion of hydrogen---, in conjunction with oxygen gas, is, according to the tenets of *antiphlogistian philosophers*, as follows:—When both gases are mixed at a temperature lower than that of ignition, or red heat, the attraction of their respective bases to the caloric is, in that case, stronger than their attraction to each other; and, therefore, they are not decomposed. But, in the heat of ignition, their bases, namely, oxygen and hydrogen, again attract each other more strongly; and hence they unite to produce water; and both the caloric and light, by which they were retained in the aerial form, are again disengaged from them, and constitute the fire.

In the system of the *phlogistians*, the basis of hydrogen gas is composed of phlogiston and hydrogen.

§ 253.

If we estimate a Parisian cubic foot of water at 70 pounds (French) and an equal bulk of hydrogen gas at 61 grains, it then follows, from the preceding proportion of hydrogen to the oxygen in their compound, water, that a cubic foot of water contains $10\frac{1}{2}$ pounds of hydrogen, capable of affording more than 1569 cubic feet of inflammable air.

§ 254.

Water can be decomposed only when placed in contact with such a body as has an attraction to its oxygen, and of superior force to that with which this last is attracted by the hydrogen. For this reason water is not decomposed on its passage through ignited silver, gold, glass, porcelain, or any other incombustible matter, but continues to be water.

§ 255.

We are as yet unacquainted with any body capable of decomposing water by attracting its hydrogen more strongly than it is attracted by the oxygen. Nature, however, seems to adopt that way in the vegetation of plants, which, exposed to the sun's light, decompose the water, absorb its hydrogen, and set free the oxygen, which is extricated from the leaves in the form of oxygen gas*.

- * Especially about noon, when they give it out as pure as that obtained from manganese. In the night-time they imbibe and digest more carbon, and hence yield more carbonic-acid gas.—Edit.

§ 256.

In the sequel, we shall shew several other methods of producing hydrogen gas, and become acquainted with several varieties of this last; all arising from this circumstance, that the hydrogen finds opportunity of dissolving various other substances, as sulphur, carbon, and phosphorus, which of course alter the nature of the hydrogen gas which is generated.

§ 257.

Hydrogen is a simple substance, and not producible by itself. It enters not only into the composition of water and hydrogen gas, but is likewise a constituent part of a great variety of other bodies. It is one of the ingredients in the mixture of bitumens, of oils, of fats, of ardent spirit, and of all the proximate constituent parts of animal and vegetable bodies. Hence it is that all combustible substances of the two organic kingdoms yield, on combustion, not only carbonic-acid (§ 230), but also water.

CHAPTER III.

*Of Salts in general.**Acids.—Alkalis.*

§ 258.

THE properties of *common*, or culinary *salt*, to be soluble in water, and to excite the sensation of taste, are likewise possessed by several other bodies, which on this account are called *salts* (*salia*, *sales*). Yet, to distinguish them from other bodies, several earths, for example, not classed among the salts, we are obliged to characterize the true salts more distinctly, by saying, that they are matters soluble in less than 200 times their weight of boiling water, and that they excite a taste on the tongue.

§ 259.

Some salts require more, others less, of water for solution. Most of them dissolve in greater quantities in boiling than in cold water. Some are fixed in the fire, others volatile. Of the last there are some that by themselves can never be separated from water.

M 3

§ 260.

§ 260.

Solid salts separate from their dissolvent water when its degree of saturation is diminished by cooling, or by evaporation, in crystalline figures (§ 37); and these *salt-crystals* exhibit a great variety of forms.

§ 261

The crystallization of salts is effected either by the cooling of their solutions that were saturated, or nearly saturated, when hot; or by the evaporation of their solvent medium. The first method is not applicable to such salts, as do not dissolve in hot water in far greater quantities than in cold water.

Particular managements on crystallizing salts in large and small quantities.

§ 262.

The benefit derived from the crystallization of salts is, that they are obtained in their own peculiar shapes, whereby they are externally distinguished; that, by this process, they part with all those impurities which either are insoluble in water, and hence are left behind at the solution and filtration, or do not enter into the crystals; and, finally, that by this means salts of different natures may be separated, because they shoot into crystals at different times, according to their various degrees of solubility.

§ 263.

§ 263.

Salt-crystals lose in heat, and some of them even in dry and warm air, their figure and transparency, and *fall to powder*, losing thereby much of their weight. They are then said to *effloresce*; and this change of form is called *efflorescence*.

Examples: Crystals of Glauber's salt, green vitriol, and carbonated or mild mineral alkali.

§ 264.

Since efflorescent crystals regain their former weight and figure by being again dissolved in water and crystallized; and since, by distilling salt-crystals, water is driven over into the receiver; this last must of course be one of their constituent parts, and be combined with them in the concrete or solid state. Such water is, therefore, called *water of crystallization*; and is in different saline crystals united in larger or smaller quantities, and in the state of greater or less fixity.

§ 265.

The species of salts produced by art and nature are considerably numerous; and remarkable differences relative to their properties and actions on other bodies have been discovered. Whence it is necessary, for a better view of them, to divide this *class* of bodies into *orders*, *genera*, and *species*. I

divide them (with regard to their *proximate* constituent parts) into two orders: that of the *simpler*, and that of the *more compound* saline substances. The genera of the first order are: the *acids* and the *alkalis*. Those of the second order are: the *neutral salts*, the *middle salts*, the *metallic salts*.

The *sweet salts* (*sugar*) are a genus belonging to the first order.

Acids.

§ 266.

Acids (*acida*) are salts of a sour taste, changing the blue colour of various vegetable pigments to a red.

§ 267.

The blue vegetable pigments are not all, however, turned red by acids.—The *syrup of violets*, the *tincture of litmus*, or paper stained with it, and also the *turnepsol-rags*, as they are called in commerce, are used as *re-agents* (§ 144) to discover whether a substance be an acid.—The tincture of litmus, so largely diluted with water as to have the appearance of sky-blue, is of all re-agents the most readily affected by acidity.

§ 268.

Some *species* of acids shew their essential distinction from each other by the different nature of their actions

actions on other bodies. Acids are commonly subdivided into *mineral*, *vegetable*, and *animal acids*; yet some acids are common to several bodies of one or more kingdoms in nature,

In the sequel, we shall consider the following as essentially different species of acids:

1. Carbonic	} acid.	11. Succinic	} acid.
2. Sulphuric		12. Tartareous	
3. Nitric		13. Citric	
4. Muriatic		14. Oxalic	
5. Fluoric		15. Malic	
6. Boracic		16. Gallic	
7. Phosphoric		17. Benzoic	
8. Of Arsenic		18. Acetic	
9. Molybdic		19. Saccho-lactic	
10. Tungstic		20. Prussic	

To which the *Chromic-acid* is now to be added.—Ed.

§ 269.

All acids are compound substances, and consist of an *acidifiable substratum* or *radical*, and of *oxygen*, which is regarded as the *acidifying basis*, or principle of acidity.

Exemplified by the phosphoric and carbonic acids. The principles of the first are phosphorus and oxygen; those of the second, radical carbon and oxygen.

§ 270.

Acids may, therefore, be decomposed and compounded. The last takes place when an acidifiable radical

radical is under combustion, and absorbs the oxygen of vital air, as was the case in the burning of phosphorus (§ 195. 203), and charcoal (§ 224). The first happens when the acid is again deprived of its oxygen by another acidifiable substance of superior affinity with oxygen; and thus the acidifiable basis, or the radical of that acid, is reproduced in a separate state.

§ 271.

Some few acids, however, of those that we know at present, have not yet been either composed or decomposed; and hence their radical is still unknown.

To these belong No. 4, 5, and 6, of the foregoing list (§ 268).

§ 272.

Several acids may be composed by art, but not again decomposed.

§ 273.

The different acids are distinguished from each other by the nature and diversity of their acidifiable radicals (§ 269).

§ 274.

The acidifiable basis of acids is either *simple* or a *compound*.

1. To acids having a *simple radical* belong, according to the antiphlogistic system, the

- | | | |
|-------------------|------------------|-------------|
| 1. Carbonic, | whose radical is | Carbon. |
| 2. Sulphuric | - - - | Sulphur. |
| 3. Nitric | - - - | Azot. |
| 4. Phosphoric | - - - | Phosphorus. |
| 5. Ac. of Arsenic | - - - | Arsenic. |
| 6. Tungstic | - - - | Tungsten. |
| 7. Molybdic | - - - | Molybdena. |

2. The acids with *compounded radicals* are, all those mentioned above (§ 268, note) from No. 11 to No. 19 inclusive. Their radical is composed of *carbon* and *hydrogen*. The acid, No. 20, has a compound quadruple basis, consisting of *carbon*, *hydrogen*, *phosphorus*, and *azot*.

3. The *unknown radical* of some acids (§ 271) is only by conjecture considered as *simple*.

§ 275.

Acids, whose radicals are composed of the same principles (§ 274, note 2) are distinguished from each other only by the various proportions of their component parts; and may, therefore, by altering those proportions, be converted into one and the same acid.

§ 276.

The acidifiable bases are capable of being saturated with oxygen in various degrees. If the saturation be complete, they are called *perfect acids*. In the *scientific nomenclature* the name of these

end

end in Latin by *icum*, in English by *ic*. But if the acidifiable radicals have not taken up as much oxygen as they possibly can, they mostly appear in a state of less acidity, and go by the appellation of *imperfect acids*. Their names are ended in Latin by *osum*, in English by *ous*.

Examples:

<i>Perfect Acids.</i>		<i>Imperfect Acids.</i>	
1. Sulphuric	} acid.	Sulphureous	} acid.
2. Nitric		Nitrous	
3. Phosphoric		Phosphoreous	

§ 277.

It is thought by some, that several acidifiable radicals admit of being over-saturated with oxygen; hence such acids have been called *oxygenated acids*, and sometimes *super-oxygenated*. But they are in fact nothing more than perfect acids (§ 276); for such an over-saturation is impossible, because oxygen no where exists in an uncombined state alone (§ 208).

Thus, in the methodical nomenclature, the *dephlogistated muriatic-acid*, as it was formerly called, has obtained the name of *oxygenated muriatic-acid*; but it is only the *perfect muriatic-acid*. The *common muriatic-acid*, which till lately has been taken for a perfect marine-acid, must be considered merely as an *imperfect muriatic-acid*.—(Note of the author.)—Yet the same terms are made use of in this translation for reasons stated in the preface.—Edit.

§ 278.

§ 278.

If the acidifiable basis be combined with oxygen, yet without shewing any of the properties of an acid, the product is then called *oxyd*. Many substances, by the absorption of oxygen, are converted into *oxyds*, but not into *acids*, of which water is a striking instance.

Alkalis.

§ 279.

Alkalis (alcalia) possess a pungent, urinous taste, and change various blue vegetable pigments to a green; red to a violet, or blue; and yellow to a brown. Blue pigments, that have been turned red by acids, are again restored by alkalis to their original colour; and *vice versa*, the actions of alkalis on such pigments are destroyed by acids.

§ 280.

Not all the blue vegetable pigments, for instance not the litmus, are converted into a green, by alkalis.—As *tests*, or *re-agents for alkalis*, are employed the *blue syrup of violets*; *paper stained red* with a decoction of *Fernambuc*, or *Brazil-wood*; or stained *yellow* by the tincture of *turmeric-root*; and, besides, the *tincture of litmus* reddened by a very weak acid, and also the *red alkanet-tincture*.

§ 281.

§ 281.

These salts are not found pure in nature, but always combined with other substances, such as the carbonic or other acids. It is the business of art to separate them from those matters. Here we speak only of the pure alkalis, which, for their solvent power on the cellular membrane and animal fibre, are also denominated *caustic alkalis*. The means of producing them will be mentioned hereafter.

§ 282.

We are acquainted with three *species of alkalis*: 1. the *vegetable alkali*; 2. the *mineral alkali*; and, 3. *ammoniac*. The two first are comprised in the common appellation of *fixed alkalis*, as they are not dissipated by fire; and the last is called *volatile alkali*, from its being easily raised by heat.

§ 283.

1. The *vegetable alkali*, or *pot-ash*, is a white solid salt, crystallizing in strongly truncated four-sided pyramids. When in the crystalline form it dissolves in water, producing a considerable coldness; but after having been dried by fire, or having lost its water of crystallization, it dissolves with production of heat. The dried salt rapidly attracts moisture from the atmosphere, and liquifies, or *deliquesces*; it is also easily fused in the fire, even at a temperature so low as 360° Farenh. Its solution
in

in water exhibits an odour like that of a room newly white-washed with lime. It cannot be volatilized by fire. In the state of fusion it readily dissolves the siliceous earth.

Synonyma: Vegetable alkaline salt, alkaline caustic-stone, soap-lees (*alkali vegetabile, lapis causticus alcalinus, lixivium saponariorum*).

§ 284.

The vegetable alkali has not yet been decomposed. It is obtained from the ashes of plants, and from several other products of the vegetable kingdom; but in these it is always united with carbonic-acid.

The translator cannot help adding, that the vegetable alkali has likewise been discovered in the *leucite*, an earth of the siliceous kind, found near Bolzena, Rome, Naples, on Mount Vesuvius, &c. in Italy: the first instance, indeed, of this alkali being a constituent part of a fossil. We are indebted for that discovery to Mr. *Klaproth's* ingenious and industrious analyses of the *leucite*, who by repeated decompositions found that this mineral consists, taking a middle number in 100 parts, of 54 flint, 24 argil, 20 pot-ash.—Vide *Klaproth's Beytrage zur chemischen Kenntniß der Mineralkörper*, 8vo. Berlin, 1797, vol. II. page 39, of which a translation is preparing.

§ 285.

2. The *mineral alkali*, or *soda* (*natrum*), with regard to the properties above-mentioned, so much resembles

resembles the vegetable alkali (§ 283), that its essential difference from it cannot be shewn, except by its combinations with acids, and by its affinities; both different from those of the former, and shewing this difference in a very striking manner.

§ 286.

Soda, or mineral alkali, has likewise not yet been decomposed. It is obtained partly from the ashes of some plants growing on the shores washed by the salt-waters of the sea, or the *soda*, as those ashes are styled in commerce; partly from neutral salts, met with in the mineral kingdom, and in which we find it combined with an acid, as for instance with the muriatic, in the common culinary salt.

§ 287.

3. *Ammoniac* (*ammoniacum*) is distinguished from the former alkalis by a very sharp, irritating, pungent smell, and by its great volatility. We are not able to produce it (pure) in the solid form; but it always appears either combined with water, in a liquid form (*liquid ammoniac*), in which state it is known by the name of *caustic spirit of ammoniac**; or in the aerial form, and then it is called *ammoniacal gas*. Its compounds are solid only when it is combined with acids.

Synonyma: Volatile alkali, urinous salt (*alkali volatile, sal urinosum*).

* The *aqua amoniæ puræ* of the London pharmacopœia.

§ 288.

§ 288.

When very strong *caustic spirit of ammoniac* is gently heated by the fire of a lamp in a retort of glass, placed in communication with the pneumatic quicksilver apparatus (§ 127) the pure ammoniac contained in the liquid ammoniac combines with the caloric, assumes the aerial form, and parts from the water. By this means the ammoniacal gas, or alkaline air, as some call it, is obtained (§ 287), shewing itself to be a peculiar species of air.

§ 289.

The ammoniacal gas is possessed of a strong, pungent, and almost suffocating smell. Like other alkalís, it produces changes on vegetable colours (§ 274). It is instantaneously decomposed by water, which absorbs its basis, *viz.* the pure ammoniac, and is thereby transformed into caustic spirit of ammoniac. It is unfit for respiration, and specifically lighter than common air; for a Parisian cubic inch of this gas at 10° Reaumur, and 28 inch barometer, weighs only 0,27488 French grains. It is dissolved by the vital, atmospheric, and azotic gases; but when carbonic acid gas is brought into contact with the ammoniacal, and heated, both gases lose their elastic state, and become a concrete solid substance; namely, *carbonat of ammoniac* *, because in this case the bases of the two gases combine with each other,

and form a product, which, at the usual temperature and pressure of our atmosphere does not appear in the aerial form.

* The *ammonia præparata* of the London pharmacopœia.

§ 290.

Ammoniac is an inflammable substance. If ammoniacal gas be mixed with oxygen gas, the mixture may be set on fire, even by the electric spark. Both kinds of air are then decomposed, and the product of their combustion is water and azotic gas.

§ 291.

From this it appears, that ammoniac is a compound of hydrogen and azot. According to Mr. *Berthollet's* experiments, its component parts are 0,807 of azot, and 0,193 of hydrogen.

* By the phlogistic system, ammoniac consists of phlogiston, azot, and hydrogen.

§ 292.

Such ammoniac as is produced from animal bodies by dry distillation (§ 115), or by their putrefaction, did not pre-exist in them ready formed; but is only generated by these processes, and composed of the hydrogen and azot contained in those substances.

Neutral

Neutral Salts.

§ 293.

Alkalis and acids shew strong attractions for each other; and they combine to form together new species of bodies, which do not exhibit the properties of their constituent parts; and where both the acids and alkalis no longer act, or serve as re-agents, in the capacity of acid or of alkali. The product arising from the combination of an acid with an alkali, and where neither the one nor the other has any excess, is called a *neutral salt*.

Experiment : By saturating nitric-acid with pot-ash.

§ 294.

Each acid produces with each of the three alkalis a particular neutral salt. The number of the last may therefore be found by multiplying the number of the acids which we know, by *three*, the number of the alkalis.

§ 295.

The distinctive properties of the different neutral salts are their taste, figure, solubility, and fixity, or volatility.

§ 296.

All acids have, in every respect, a nearer affinity with the fixed alkalis (§ 282) than with ammoniac; and in many cases they likewise possess a stronger attraction for the vegetable than for the mineral alkali.

CHAPTER IV.

Earths.

§ 297.

EARTHS (*Terræ*) are incombustible bodies, fixed in the fire, and, without some intervening medium, insoluble in 200 parts (by weight) of boiling water.

§ 298.

Simple Earths (*Terræ simplices*) are those which do not admit of any farther decomposition into heterogeneous constituent parts. In nature they are always found united amongst themselves, or with other substances.

§ 299.

We are at present acquainted with *eight* different simple earths: 1. The *Siliceous*; 2. *Calcareous*; 3. *Magnesian*, or *Talcy*; 4. *Argillaceous*, or *Aluminous*; 5. *Ponderous*, or *Barytic*; 6. *Strontian*; 7. *Circon*; 8. and *Austral Earth*.

The *Austral earth* should be erased from this list
§ 349. n. and *Glucine* added.—Ed.

Middle Salts.

§ 300.

Most of these earths unite with acids in a way similar to that of alkalis. They deprive them of their acidity, and render them incapable of acting as acids. Such earths are, the calcareous, magnesian, argillaceous, and stontian.. For this property they are also styled *alkaline* or *absorbent* earths, and the product arising from their combination with an acid is called a *middle salt* (*sal medium*).

§ 301.

The middle salts are, as to their external qualities, very analogous to neutral salts (§ 293). They are distinguished from each other as well by the difference of their earthy basis as by that of their acid; and each alkaline earth produces with each different acid a particular middle salt. Yet some of these combinations are of so difficult a solubility as prevents them from being classed with salts (§ 258), and assigns them a place among stones and earths*.

* For instance: *Gypsum, Lime-stone.*

§ 302.

Each of the acids takes up only a certain fixed quantity of any alkaline earth. A middle salt, to be a true perfect salt of that kind, must contain no excess

cess either of the acid or of the earth. There are, however, some middle salts, that are employed only when they have a redundancy of acid.

§ 303.

The alkaline earths do not all possess an equal degree of affinity with acids. Some of them surpass, others are in this respect surpassed, by the alkalis.

Of Siliceous Earth. Glafs.

§ 304.

The *siliceous earth (flex)*, or *flint*, is the predominant constituent part of those earths and stones, called siliceous. It is found in its purest state in *quartz*, *quartz-sand*, and *rock-crystal*. By itself it is insoluble in water and acids, except the fluoric; it is destitute of taste, and infusible.

§ 305.

Yet however refractory in the fire the siliceous earth may be when alone, it is easily rendered fusible by the assistance of fixed alkalis, pot-ash, or soda. These dissolve it in a heat strong enough for fusion, and unite with it to form a new compound, *glafs*.

§ 306.

Whence *glass* (*vitrum*) is a combination of the siliceous earth and a fixed alkali. The earth acquires fusibility from the alkali, and the alkali loses thereby its solubility in acids and in water. The more alkali is added to the composition, the softer and more fusible becomes the glass; but at the same time it is rendered less capable of resisting the action of water and acids. The goodness of glass depends on the purity of its ingredients, on their just proportion to each other, and on their being long kept very liquid during the fusion.

§ 307.

Common *green glass* is made by fusing together sand and ashes containing alkali. For the whiter and finer *crystal glass*, pot-ash, soda, and the purer kinds of siliceous earth, quite free from ferruginous matters, are used. Some other additions are at times admixed, partly to serve as fluxes to the flux, partly to give a greater density to the glass, and partly to destroy the combustible matters of the ingredients. These additions are various in the different glass-manufactories, such as gypsum, litharge, nitre, white arsenic, and the black oxyd of manganese.

§ 308.

The ingredients destined for the composition of glass by melting are previously well comminuted and

and mingled.—This mass, called *frit*, is first, by continued agitation, thoroughly ignited and calcined in the calcining furnace, for the purpose of driving off the carbonic acid gas, which otherwise would cause small cavities, or air-bubbles in the body of the glafs. The *glafs pots* or vessels made of baked and refractory clay, are then filled with the *calcined frit*, standing in the *glafs-furnace* on an elevated flooring, called the *bench*, in such a manner that they may be come at by the glafs-maker by means of *holes*, or *apertures*, in the furnace. The frit is here melted by the fire, and its fusion kept up until the whole is well incorporated, and flows in a sufficiently thin state as an homogeneous mass, called *glafs-metal*, and until, on trial, no more bubbles appear. The extraneous salts that are contained in the pot-ash, and are not vitrified by the fusion, but float above the metal, are carefully taken off with a ladle, and have received the name of *glafs-gall* (*sel vitri*).

The glafs-metal, thus well purified from foreign matters, and in full fusion, is formed into vessels of the requisite shape, by blowing and other manual treatment, and also sometimes by being cast in moulds. To diminish the brittleness of glafs thus manufactured, it is again heated in the *cooling furnace*, and then gradually suffered to *cool*; which is called *tempering* or *annealing*.

§ 309.

If metallic calces be melted with glass they tinge it of various colours:—Thus the common green glass acquires its tinge chiefly from the particles of iron, interspersed in the sand and ashes made use of. To this subject belong the *glass-pastes*, as they are denominated, and the *artificial gems*. Their chief substance is a pure, hard, *crystal-glass*, coloured by metallic oxyds. The addition of calx of lead renders the glass more fusible. When oxyd of tin is added, it becomes thereby more or less opaque. To these glass-pastes the *enamel* likewise belongs, wherewith metals are covered, and which is either transparent or opaque, white or coloured; and also the pigments used in *porcelain* or *enamel-painting*.

A recipe for crystal-glass.—Take one ounce of pure quartz, make it red hot in a crucible, quench it afterwards in water, and repeat this until it be sufficiently soft to admit of being triturated. Levigate it then finely, and mingle it accurately with half an ounce of pure salt of tartar, three drachms of calcined borax, one drachm and a half of flake white, and a scruple of nitre.—Put this powder into an assaying crucible, luted, and gradually heated. When the frit has been for one hour in fusion, let it cool by degrees, break the crucible, and take off the clear glass.

§ 310.

The more alkali is added to the frit, the more readily the glass flows, but so much the less will it

resist the action of acids and water, and the influence of the atmosphere. Nay, by an over proportion of alkali the nature of glafs may be so changed as to be totally soluble in water, and even to deliquesce in the air.

§ 311.

When, therefore, one part of quartz-sand; and four parts of purified pot-ashes are melted, in an iron pot placed before the bellows, till the whole mass flows uniformly and thinly, a glafs is obtained which excites a sharp and caustic sensation on the tongue; is completely dissolved by water, and deliquesces by the mere moisture of the atmosphere. The mass of glafs thus deliquated in the air, and dissolved in water, is styled *liquor of flints* (*Liquor silicum*).

§ 312.

Every acid precipitates the siliceous earth from the liquor of flints (§ 311); and the precipitate has the appearance of a jelly, as long as it continues moist. If the liquor of flints be diluted with a great quantity of water, as for instance, in the proportion of 24 parts to one of the vitreous matter, and in this state an acid be poured upon it, no perceptible precipitate will subside, but the siliceous earth continues suspended in the fluid, and is invisible on account of its transparency. It may be made to appear by evaporating part of the water.

The

The liquor of flints, on account of its affinity with the carbonic acid, is also, in course of time, decomposed by mere contact with air.

Of Calcareous Earth.

§ 313.

Calcareous earth (*Calx*), or *lime*, is in nature never met with pure, but always combined with an acid, and very frequently with the carbonic, as in chalk, common lime-stone, marble, and calcareous spar; hence the carbonat of lime is usually called *crude calcareous earth*. Since the carbonic acid may be separated from it by ignition, this becomes a means to exhibit the calcareous earth in its pure state.

§ 314.

For this purpose an earthen retort is filled with clean powdered marble, or other pure lime-stone, and being first joined with the pneumatic apparatus, it is heated by degrees till the whole mass is red-hot.—A quantity of carbonic acid gas is disengaged. The fire must be kept up till no more gas comes over. The remainder of the calcareous earth in the retort is now remarkably altered; it effervesces no longer with acids on solution, as it did before; and it has an acrid, burning, alkaline taste, which it did not possess before ignition. In this state it is called *burnt*, or *quick lime* (*calx viva, usta*).

§ 315.

§ 315.

This quick-lime is to be looked upon as pure calcareous earth; now freed by burning from the carbonic acid and water, with which it was naturally united. Burnt lime produces a strong heat with the water by which it is *slacked*; it imbibes and fixes it very firmly; on adding more water it is at last completely dissolved, but requires 680 times its weight for solution. This solution is called *lime-water* (*aqua calcis vivæ*), possesses a pungent alkaline taste, and acts on vegetable pigments (§ 279) like an alkali.

§ 316.

Lime-water remains unchanged in well-closed vessels; but when exposed to open air, it is covered with a thin pellicle, called *cream of lime*, which on becoming thicker breaks and falls to the bottom, making room for another new crust, till at last all the lime is separated.

§ 317.

This cream, formed on the surface of lime-water, is again a crude calcareous earth; *i. e.* a carbonate of lime, of no taste, insoluble in water, and again effervescing with acids. The cause of the alterations undergone by lime-water exposed to air, originates from the carbonic-acid of the atmosphere, which is powerfully attracted by the pure earth of the lime-water,

water, and whereby the earth is reduced to its former state of crude lime.

§ 318.

The same changes take place with quick-lime itself when in contact with common air. It gradually attracts not only fixed air, but also moisture from the atmosphere; and being thereby gradually slacked, it falls to powder, and loses its sharpness.

§ 319.

Calcareous earth is infusible without addition, even in the strongest fire. Added to glass-frit it may be melted, and yields with it a milk-white, pellucid glass.

§ 320.

The nature of *mortar*, or paste of lime, sand, and water, whose hardening is a species of crystallization, depends on the absorption of water by quick-lime, which not only imbibes, but also fixes, or transforms it into water of crystallization. A well-proportioned addition of sand increases the firmness of the mortar by adhesion to the calcareous earth. The mortar, to be of good quality, ought to be made of lime properly burnt, which after slacking has been carefully excluded from the access of air, and prevented from drying, before it be worked up with sand. It is only by a thorough drying, after the absorption of carbonic-acid, that mortar acquires its

its hardness. Before drying it is greatly injured by frost.

Magnesia, or Talcum.

§ 321.

The *magnesian-earth* (*magnesia*)* is a constituent part of talc, soap-rock, steatites, serpentine, asbestos, &c. and is never found pure in nature. It exists besides, neutralized, in the Epsom or bitter salt, in the mother-lye of most brine-springs, and in sea-water.

* (*Terra muriatica, magnesia salis Epsomiensis*). The author, as the rest of Germans, at present, calls it *earth of talc*.—Edit.

§ 322.

The usual method of procuring pure magnesian-earth is to precipitate it by means of pot-ash from Epsom salt, wherein it is combined with the sulphuric-acid into a middle salt, and is thrown down by the alkali as a carbonat of talc, or *aërated magnesia*.

To effect this any portion, at pleasure, of Epsom salt is dissolved, by boiling in a large quantity of clean water, and to the strained solution a lixivium of purified pot-ash is successively added, till no more precipitate is afforded. The next step is, to boil
the

the whole mass, and to let its fluid parts run through a linen-cloth sewed in a conical form (the *manica Hippocratis* of former chemists). The earth remaining behind in the cloth is once more boiled with much clear water, and returned on the filter. After which it is freed, byedulcoration (§ 13), from all adhering saline particles, and lastly dried.

Magnesian-earth thus obtained is still combined with carbonic-acid, taken up from the alkali, and which is expelled by ignition in a covered crucible. It is now called burnt or *calcined magnesia* (*magnesia usta*); and in this state only, when no longer effervescing with acids, it may be considered as pure magnesian-earth.

§ 323.

Burnt magnesia is neither caustic nor acrid, like burnt calcareous earth (§ 314); it is neither soluble in water, nor becomes hot when added to it. It absorbs again the carbonic-acid gradually from the atmosphere, and is thereby again rendered effervescent with acids. By alkalis it is not dissolved in the humid way. When alone it does not melt in common fire. Mingled with siliceous and calcareous earths, it melts in a strong heat.

Of Alumine, or Argillaceous-Earth.

§ 324.

Argillaceous earth, or *alumine* (*argilla*), is a component part of argil and every species of clay; but ought not to be confounded with the *clay* itself, in which it is always united to filiceous-earth. Hitherto it has not been found pure any where, except in the gardens of the *Pædagogium* (public schools) at Halle.

Synonyma: Aluminous-earth (*terra aluminis*); pure argil, pure clay (*argilla pura*).

§ 325.

Though argillaceous-earth may be diffused, suspended, or divided in water into uncommonly fine particles, it is, however, not soluble in it. With a small quantity of water it forms a tenacious, ductile, kneadable paste, which shrinks very much by drying, and proportionally in all its dimensions; and when suddenly brought into strong fire, before it is completely dry, it cracks, bursts, and flies in pieces. If, after being thoroughly dried, it be baked in the fire, it contracts a great deal, and receives by burning such a degree of hardness as to strike fire with steel. Clay, when baked, however

finely pulverized, is no longer capable of being kneaded with water into a ductile paste.

§ 326.

With carbonic-acid the aluminous-earth has no affinity. One of its most characteristic properties is, that it is dissolved by alkalis in the humid way, and constitutes with them several compounds, which again are decomposed by acids, though some of them only in part.

To these belong

1. *Argillaceous pot-ash;*
2. *Argillaceous soda;*
3. *Argillaceous ammoniac.*

§ 327.

Alumine possesses a powerful attraction to calcareous-earth, so much so, that it deprives lime-water of it entirely, if, when recently precipitated and pure, it be mingled and agitated with it.

§ 328.

The most intense heat of a furnace is not able to melt argillaceous-earth alone; but it becomes fusible when lime is added.

Use of Clay for Pottery-Ware.

§ 329.

Clay is indebted to the argil which it contains for some of its principal characters, such as its softness and greasy feel, its ductility or clamminess on being worked up with water, its shrinking and contraction while drying and baking. It is always united with siliceous-earth, which, even without exception, is its predominating constituent part. *Pure clay* consists only of argillaceous and siliceous-earth; it is *fatter* in proportion as it contains more of the first, and *poorer* or more *meager* according as the *filex* abounds. By itself it is not fusible in fire, does not effervesce with acids, and turns completely white by burning. Lime, magnesia, gypsum, sparry fluor, and ponderous spar, promote its fusion.

§ 330.

Clay is commonly mingled with more or less of calcareous, siliceous, ferruginous, and also fine bituminous particles; and for this reason all sorts of clay are not infusible and colourless. The yellow or red colour, after baking, always proves the presence of iron. Clay may be purified from sand and groffer siliceous parts by elutriation (§ 12).

What is the cause of the odour of some species of clay on breathing upon them?

§ 331.

In common life clay is used for a variety of purposes, according to its greater or less purity; and, what depends on this, according to its colour and capacity, or incapacity of fusion.

§ 332.

The baser sorts of clay, especially the coloured ones, are employed for making *tiles* and *bricks*. With this view the clay is wrought with water, interspersed and mingled with sand, shaped in moulds, dried in the air, and burnt either in particular *brick-kilns*, or in such as are united with lime-kilns. In bricks that are commonly sold this great defect occurs, that they are manufactured of clay containing too much calcareous-earth; which, therefore, melts in the fire. For this reason these bricks are but slightly burnt; whence they do not resist moisture and the decay produced by the influence of air.

§ 333.

The common fire-proof, or refractory clay, is used in the manufactures of *common pottery*. After having undergone the proper preparations by washing, and kneading with water to a due consistence and fineness, it is formed on the wheel into vessels, which, after being gradually dried in the shade, are coated with oxyds of lead, as litharge; on such parts as are intended to be glazed, and finally baked
in

in the potter's furnace or kiln; where, at the same time, the calces of lead melt to a glass, which covers the surface of the vessel like a varnish. The common fault found with such goods is their not having been sufficiently burnt.

Of glazing with lead in regard to health, and its remedy.

§ 334.

Good refractory clay, with an addition of sand, is likewise the material for *melting-vessels* (§ 101). Pure, uncoloured clay, which is not too meager, is employed for making *tobacco-pipes*.

§ 335.

Such pottery-ware as is manufactured of purer and finer clay, and coated with better glazing, is what is termed *fayence*, or *spurious porcelain*. For this manufacture the clay is first properly prepared by washing and kneading. The vessels formed of it are then fully dried in the air, and first slightly burnt, to be afterwards coated with the *glazing-powder*. This last is done by dipping the vessels into water, which holds the finely-pulverized glazing materials diffused; the vessels, when withdrawn, imbibe the water, and the glazing materials remain uniformly fixed on their surface. When again completely dry, they are placed in earthen *saggars* (*cassettes*), or covered pots, and once more exposed

to a heat sufficiently strong to flux the fusible parts of the glazing ingredients; while, at the same time, the clay-vessel under them is burnt to hardness. The glazing of pottery, owing to its calx of tin, is not transparent.

The usual composition for glazing: 1 part of quartz-sand, $\frac{3}{4}$ parts of pot-ash, 2 parts of calx of lead, and 1 to $1\frac{1}{4}$ part of calx of tin.

§ 336.

The genuine *stone-ware*, or *stone-porcelain*, is composed of that kind of clay which in a strong fire, either by its own nature, or by virtue of some additions, gently shrinks, but without absolutely melting. The surface of those wares is glazed by volatilizing, in the white heat of the furnace, a certain quantity of common salt, the vapours of which produce a kind of glazing on the surface of the clay. The *faggars* in which this manufacture is burnt are perforated. If the clay be too fat, or contains too much argil to make it fit for stone-ware, it is corrected by adding powdered flint, or sometimes marle, fluor-spar, or chalk. A great deal of what is at present sold for porcelain, is nothing but stone-ware. It is easy to discern these two species by their fracture. The bottles intended for holding Seltzer-water are true stone-ware, though of an inferior kind.

§ 337.

By *genuine*, or true *porcelain*, such pottery-ware is understood as is infusible in the strongest fire excited in furnaces, is hard, but not so brittle as glass; proof against any sudden and great changes of heat and cold; finely grained, dense, and without gloss on the fracture, not glassy, and of a peculiar transparency.

§ 338.

Several compositions of mingled earths may yield a true porcelain by being burnt; and the porcelains of various countries differ really in their mixtures. But the principal basis of any true porcelain is that kind of clay which becomes white by baking, and which, either by intermingled heterogeneous-earths, or by particular additions, undergoes in the fire an incipient *vitrifaction*, in which the true nature of porcelain consists. Feld-spar and gypsum, if added, may give that property to infusible clay.

§ 339.

When porcelain is to be made, the clay is properly selected, carefully elutriated, and again dried. It is then finely sifted, and most accurately mingled with quartz, ground very fine; to which there is besides added some burnt and finely pulverized gypsum. This mass is worked with water to a paste, and duly kneaded; it is usually suffered to lie in this state for years; and is, besides, wetted with certain (perhaps quite unnecessary) *corrosives*, that

are kept secret. The vessels and other goods formed of this mass are first moderately burnt in earthen pots to receive a certain degree of compactness, and to be ready for glazing.—This glazing consists of an easily melting mixture of some species of earths, as the petrosilex or chert, fragments of porcelain, and gypsum, which, when fused together, produce a crystalline, or vitreous mass, that after cooling is very finely ground, and suspended in a sufficient quantity of water. Into this fluid the rough ware is dipped, by which the glazing matter is deposited uniformly on every part of its surface. After drying, each article is placed in a separate *cassette*, and thoroughly baked or burnt in the violent heat of the *porcelain-furnace*.—It is usual to decorate porcelain by paintings; for which purpose enamels or pastes, coloured by metallic oxyds (§ 309), are used, so easy of fusion as to run in a heat less intense than that in which the glazing of the ware melts.

§ 340.

To the above the *porcelain* invented by *Reaumur* is analogous, which may be made of glass by a kind of *devitrification*; that is, by depriving it in part of its vitreous qualities. For when glass, best of all hard and green glass, is put into a vessel, and covered all over with burnt gypsum, or sand, or lixivated ashes, or calcined and pulverized bones, or lime *, and in this situation exposed to fire, in-
creasing

creasing its vehemence gradually till the glass be thoroughly ignited, first for a sufficient time in red-heat, and at last in white-heat; it will then be found converted into a species of porcelain.

* These bodies are in this case called *cementing substances*, not to be confounded with the *cementing powders* (§ 82).—Edit.

§ 341.

To explain the cause of the formation of this porcelain, we must recollect that glass is a compound of fixed alkali and siliceous earth (§ 306, seq.) When, therefore, in the above process (§ 340) the red-heat is long continued, part of the alkali melted by heat exsudes, and the remaining part is incapable of effecting a total vitrification of the siliceous-earth in the glass used for the experiment. Hence the glass is compelled to assume the state of porcelain, or semi-vitrification. The cementing substances are, in this case, of no other service than that of preserving the figure of the body intended to be devitrified.

Ponderous Earth, or BARYTES.

§ 342.

Ponderous or heavy earth (*barytes*) * is always found in combination with acids; as with the sulphuric (*ponderous spar*), or with the carbonic (*witherite*).

(witherite). To procure it pure, art must be employed.

* *Terra ponderosa officin.*

§ 343.

For this purpose one part of white and pure ponderous spar, reduced to a subtile powder, is accurately blended with three parts of salt of tartar, and together with this addition kept in a covered crucible for some hours in a red-heat. After the concrete mass has grown cold, it is pulverized, and boiled in distilled water, till the filtered lye absolutely ceases to give any saline taste. The earth remaining in the filter is then dissolved in muriatic-acid, and suffered to crystallize. The tabular crystals are selected and dissolved in distilled water, and precipitated from the solution by means of pure carbonated alkali; whereupon the precipitated earth is properly edulcorated. It is now pure ponderous earth, combined only with carbonic-acid, of which it may be freed by continued ignition.

The best method of obtaining ponderous earth in its utmost purity seems to be that of *Vauquelin* and *Fourcroy*, in the *Annales de Chimie*, Tome XXI. page 276, by decomposing nitrat of barytes (§ 489) by the action of fire. *Nicholson* has given a translation of that method in his excellent *Journal of Natural Philosophy, Chemistry, and the Arts*, Vol. I. page 535. —Edit.

§ 344.

This pure and burnt barytes is not fusible by itself. Water dissolves it in but very small quantity; one part of the earth requiring 900 parts of water to be dissolved *. The solution is pungent to the taste, and acts as an alkaline substance on vegetable colours. By exposure to the air it is rendered turbid, because the ponderous earth attracts the carbonic-acid, and is rendered thereby insoluble.

- * Yet, when prepared in the manner of *Vauquelin* (§ preceding, note,) it absorbs water with extreme avidity, melts with a hissing noise, heats considerably, solidifies the water, and forms compages like beaten plaster. Cold water dissolves one twenty-fifth part of its weight; boiling water more than half.—Edit.

Strontian-Earth.

§ 345.

The *Strontian-earth* exists in a fossil, which, from its native place *Strontian*, in Scotland, has obtained the name *Strontianite*, and in which this earth is combined with carbonic-acid. But it is likewise one of the constituent parts of ponderous spar, from which it may be separated, if the fluid muriat of barytes, made for obtaining this earth according to § 343, be farther crystallized after the first crystals in the shape of tables, which are the crystallized muriat of barytes, have shot, and been removed.

For then new crystals, needle-shaped and radiated, will be formed; and these are the muriat of *Strontian-earth*. From this solution in muriatic-acid the Strontian-earth may be precipitated by aerated or carbonated alkali.

§ 346.

The natural carbonat of Strontian-earth does not part with its carbonic-acid even in a very strong calcining fire but with excessive difficulty. If this acid be artificially combined with it, it may be more easily separated. This Strontian-earth, when pure, and consequently deprived of carbonic-acid, possesses a corrosive or caustic taste. It is soluble in a large quantity of boiling water, *viz.* in 250 times its weight; but it requires more of cold water to be dissolved. The solution tastes like strong lime-water, and loses its clearness in the air by attracting from it carbonic-acid. The saturated solution of Strontian-earth made in boiling water, if, after filtration, it be immediately and carefully preserved in a glass-bottle, shoots into clear, pellucid crystals, of a rhomboidal form and caustic taste; which, however, lose their transparency on exposure to air.

§ 347.

Strontian-earth is, without addition, infusible even in the most violent fire; but in a crucible made of clay, it melts with the argil, forming with it a glass.

Circon-

Circon-Earth.

§ 348.

The *Circon-earth* (*circonia*) was discovered by Mr. *Klaproth* first in the *circon* (*jargon of Ceylon*), and afterwards in the *hyacinth*, as a predominant principle and a peculiar species of earth. It is not soluble in water. Acids dissolve it; yet with the carbonic it has no affinity. By caustic alkalis it is not dissolved in the humid way; it does not melt by itself, nor with fixed alkalis; yet with borax it melts, and is converted into glass.

Austral-Earth.

§ 349.

The *Austral-earth* (*Cambria*) was discovered by the late Mr. *Wedgwood* in a kind of earth from *New South-Wales*. It is insoluble in water, in caustic lye, and in acids, with exception of the concentrated muratic-acid, assisted by heat. Simple water precipitates it again from this solution. Without addition, the strongest fire will not fuse it.

Terra Sydneia Australis are other appellations for this earth. It is at present no longer considered as a different species of earth, since Mr. *Klaproth* has by his analysis found that it is not so. Mr. *Charles Hatchet* has also examined two specimens, received from Sir *Joseph Banks*, President of the Royal Society; and the result of his ingenious researches is, that *this earth has not the properties announced by Wedgwood, but contains much silica with alumine, carbonat of iron, and a small*

small portion of water, or volatile matter, but no other substance. His paper on this head is inserted in the Philosophical Transactions for the year 1798, and also in *Nicholson's Journal*, Vol. II. page 72.—
Translator.

Glucine-Earth.

To the above earth *glucine* is at present added. It is white, insipid, insoluble in water, but soluble in most of acids, and likewise in fixed alkalis; adhesive to the tongue, infusible *per se*, but with borax fusible into a transparent glass.—The following are said to be its *specific characters*: 1. Its salts are saccharine; 2. it is very soluble in the sulphuric-acid by excess; 3. it decomposes the aluminous salts; 4. is soluble in carbonat of ammoniac; 5. is completely precipitated from its solutions by ammoniac; 6. and its affinity for the acids is intermediate between magnesia and alumine.

As none of the known earths unite the last-mentioned six properties, *Vauquelin* considers it as a distinct earth. He discovered it on analysing the beryl, and called it *earth of beryl*, of which it constitutes 16 parts in 100. He also found it in the *emerald of Peru*. It has since been called *glucine*, from the Greek word γλυκὺς (sweet), on account of its most characteristic property of forming saccharine salts. Future experiments must shew whether this substance may maintain its place among the earths as a distinct species.—See *Annales de Chimie* XXVII. page 155 and 170 seq.; or *Nicholson's Journal*, Vol. II. p. 358 and 393.—Edit.

CHAPTER V.

*Mineral Acids, and their Combinations with Alkalis and Earths.**Carbonic Acid.*

§ 350.

WE have already (§ 227) become acquainted with the *carbonic acid*, as the basis of carbonic acid gas. This acid is always in the ærial state, at any temperature and at any pressure of the atmosphere which we know of, and cannot be produced, or exhibited by itself in a dense, concentrated, fluid state.

Dr. *Black*, of Edinburgh, in the year 1755, first noticed this air in crude lime. *Macbride*, in 1764, and *Jacquin* confirmed it by new experiments. *Priestley* set the matter in the fullest light, and *Bergman*, in 1772, demonstrated that this gas was of an acid nature, and called it *ærial acid*.—Ed.

§ 351.

The æriform carbonic acid is procured, in the easiest way, by dissolving chalk or marble in diluted sulphuric acid; and the process is performed in a *disengaging bottle* (123) placed in conjunction with the pneumatic apparatus.

§ 352.

§ 352.

Fixed air, or carbonic acid gas, is absorbed by cold water; that is to say, cold water deprives the caloric of its basis (§ 227), and consequently decomposes the carbonic acid gas. Water imbibes, at the temperature of 50° Fahr. about an equal volume of this gas. This kind of solution is promoted by shaking. By warmth and heat the attraction of carbonic acid for caloric is made stronger than for water; and hence the acid is again extricated from the water, in the form of bubbles. *Carbonated water* *, or water impregnated with fixed air, therefore loses, by boiling, all its carbonic acid; which, besides, is separated from it by freezing, or by the action of the *air-pump*.

* Also called aerated water (*aqua aerata*).

§ 353.

The sourness or acidity of carbonic acid, in water saturated with it, is but weak; and the acid shews its presence by turning the blue tincture of litmus red. The *acidulous mineral waters*, as that of *Eger*, *Seltz*, *Pyrmont*, &c. are natural solutions of carbonic acid in water; which, by virtue of this acid, hold some other matters in solution, which could not be dissolved by pure water.

Artificial preparation of aerated acidulous waters.

§ 354.

§ 354.

Carbonic acid combines with alkalis and earths to form neutral and middle salts called *carbonats*, or carbonated salts; whose distinguishing characters are, to effervesce with those acids which are possessed of greater affinity with alkalis than carbonic acid. Alkalis neutralized by carbonic acid have also been called *mild*, in contradistinction to *pure* or *caustic* alkalis.

§ 355.

It is on account of this stronger attraction to carbonic acid, that this gas is more rapidly decomposed by alkalis and alkaline earths than by simple water (§ 352). If therefore caustic lye, or lime-water, be poured into a glass containing this gas, and the vessel be corked and well shaken, a vacuum immediately takes place. In this way it is easy to saturate caustic lye with carbonic acid, and still more commodiously by the apparatus of *Pelletier* *.

* *Neues Journal der Physik*, Vol. I. page 265. (Published by the author).—*Welther* has described an apparatus for saturating pot-ash and soda with carbonic acid. The intention of this apparatus is to afford an uninterrupted contact between the alkali and carbonic-acid gas, and to proportion the disengagement of the gas to its fixation.—*Welther's* paper has been given translated from the *Annales de Chimie* XXVII. p. 53. in *Nicholson's Journal*, Vol. II. p. 369.—Ed.

§ 356.

1. *Carbonat of Potash*, or the mild vegetable alkali, crystallizes in four-sided oblique columns,

terminated by two surfaces obliquely truncated. The crystals do not deliquesce, or decay in air. Their taste is alkaline, but not caustic. They still act on vegetable pigments as if they were mere alkali. Water dissolves at 50° Farenh. $\frac{1}{4}$ of its own weight of them, but in heat $\frac{5}{8}$. The crystals of this salt contain, according to *Pelletier*, 0,40 parts of pure vegetable alkali, 0,43 of carbonic acid, and 0,17 of water.

Synonyma: Aërated vegetable alkali (*alkali vegetabile aëratum*).

§ 357.

Common pot-ash (*cineres clavellati*) or mild vegetable alkali, obtained by lixiviation from the ashes of plants, is already by nature combined with carbonic acid, because that acid is produced in the combustion of plants (§ 230); and for that reason it effervesces with acids. *Pearl-ashes*, or *depurated pot-ash* (*cineres clavellati depurati*), and *salt of tartar* (*sal tartari*), are only in part carbonats; and hence are deliquescent in the air, (*oil of tartar*, *oleum tartari per deliquium*) and, besides, of a more acrid taste.

§ 358.

Our atmosphere is always impregnated with a portion of carbonic acid gas; hence a lixivium or lye of pot-ash is, by long exposure to air, converted into a carbonat, and becomes crystallizable.

§ 359.

§ 359.

By heat, the carbonat of pot-ash is deprived of its carbonic acid, and water of crystallization. Nevertheless it is difficult totally to discharge the alkali of that acid by a mere red-heat.

§ 360.

2. The *carbonat of soda*, or the mild mineral alkali, forms crystals of four-sided columns, having their ends, in opposite directions, obliquely truncated. By this, all the lateral surfaces of the column are pentagons. According to *Bergman's* statement, they contain 0,20 of mineral alkali, 0,16 of carbonic acid, and 0,64 of water; they effloresce in dry and warm air, or fall to a white powder; they excite an alkaline taste on the tongue; are re-agents with vegetable colours; and require, at the temperature of 50° Farenh. 2,4 parts of water for solution, but scarcely an equal quantity of it when boiling.—The properties of this neutral salt, when exposed to fire, are like those of the last § 359.

Synonyma: Salt of soda (*sal sodæ*), aerated mineral alkali (*alkali minerale aeratum*).

§ 361.

The carbonat of soda (*NATRON*, *Trona* of the Egyptians)* is found ready formed by nature in

various countries: in upper *Hungary*, *Egypt*, *Fezzan*, *Persia*, the *East Indies*, *Siberia*, and especially at the bottom of *salt-seas*, dried up by the sun's heat; and also in some mineral waters, as in that of *Eger* on the frontiers of *Bohemia*. It is, besides, obtained by lixiviation from *soda*, or the ashes of various plants growing on the sea-shore and impregnated with salt.

By the word *natron*, the ancients probably understood the same substance; and this name of *natron præparatum*, procured from the lye of the *Barilla*, is given to it in the *Lond. Pharmac.*—Edit.

§ 362.

According to *Bergman*, the carbonic acid has not so near an affinity with the mineral as with the vegetable alkali.

§ 363.

When ammoniacal (§ 287) and carbonic acid gas are mixed over mercury, in the pneumatic apparatus, both gases quit their elastic state, and their bases unite into a concrete salt, *the carbonat of ammoniac*; while at the same time their fixed caloric is set free. If very strong liquid ammoniac (§ 287) be poured into a bottle filled with carbonic acid gas, and afterwards stopped up, a carbonat of ammoniac will be formed, shooting into crystals, and the gas disappears.

Synonyma: Aërated volatile alkali (*alkali volatile aëratum*), volatile salt of ammoniac (*sal volatile salis ammoniaci*).

The London College of Physicians orders this salt to be prepared by depriving muriat of ammoniac of its marine acid by chalk; which in the process exchanges for it its carbonic acid. It calls the product, *ammonia præparata*.—Edit.

§ 364.

The crystalline figure of carbonated ammoniac is not well decided: *Romé de Lisle* asserts it to be a four-sided, compressed, truncated column, terminated by a dihedral summit. These crystals have a strong, pungent taste and odour; vegetable colours are affected by them; and they contain, as appears by *Bergman's* analysis, 0,43 ammoniac, 0,45 carbonic acid, and 0,12 of water. This salt is volatile in heat; yet without being decomposed.

§ 365.

Ammoniac has not so strong an attraction for carbonic acid, as the two fixed alkalis have.

§ 366.

The carbonic acid gas is no less decomposed by lime-water than by caustic alkalis, since the carbonic acid combines with calcareous earth. And because the carbonat of lime arising from this combination is insoluble in water, the lime-water must, of course, be thereby rendered turbid (§ 317.)

§ 367.

4. This *carbonated calcareous earth*, known likewise by the name of *crude calcareous earth* (*calx cruda*) abounds in nature, in the various forms of chalk, lime-stone, marble, calcareous spar, &c. It is devoid of taste, and insoluble in water. It is therefore beyond the power of art to exhibit it in the crystalline form, as is often done by nature. The component principles of the transparent calcareous spar are said by *Bergman* to be 0,54 calcareous earth, 0,36 carbonic acid, and 0,10 of water.

Synonyma: Aërated calcareous earth, or aërated lime (*calx aërata*), mild calcareous earth.

§ 368.

Carbonat of lime may become soluble in water, by an excess of carbonic acid; as also for this reason, water impregnated with fixed air dissolves the calcareous carbonat. This solution is again decomposed by boiling; as the superabundant carbonic acid is caused, by heat, to fly off in the form of gas (§ 352).—On this ground depends the formation of calcareous sediments or incrustations on the bottom and around the inside of vessels, wherein water holding calcareous particles is often boiled.

§ 369.

The carbonat of lime in a continued red-heat, parts with its carbonic acid, and is thus converted into burnt or quick-lime (§ 314).

§ 370.

§ 370.

The carbonic acid has a greater affinity with calcareous earth than with alkalis; and hence the latter are deprived of their carbonic acid by lime. For this reason a turbidness directly takes place in clear lime-water, when mild, or carbonated alkali is added.

§ 371.

Upon this principle rests the preparation of caustic alkaline lyes, and of caustic alkali. For this purpose, one part of depurated pot-ash is boiled with two parts of lime recently burnt, and previously flaked in a sufficient quantity of water, and the hot lye is strained through a white linen cloth. This lye should not effervesce with acids, or cause a cloudiness in clear lime-water, otherwise it still contains a portion of carbonic acid.—As a general rule, the proportion of burnt lime to the alkali ought to be regulated by the greater or less portion of fixed air contained in the alkali.

The vegetable alkali thus rendered caustic is the *kali purum* of the London College of Physicians, to distinguish it from common potash (§ 357), or the *kali impurum*, which, besides, is in most cases contaminated with vitriolated tartar.—Edit.

§ 372.

Caustic alkali precipitates the carbonat of lime, dissolved in water impregnated with carbonic acid;

but the precipitate is what it was before the solution (§ 367), carbonat of lime, or crude calcareous earth.

§ 373.

5. The *carbonated talc or magnesia* has an earthy appearance, is tasteless, and scarcely, if at all, soluble in water. It is procured by the method stated above (§ 322), viz. by precipitating a solution of Epsom-salt by means of a carbonated fixed alkali. On being burnt, it loses its carbonic acid (§ 322), like calcareous earth.

Synonyma: Aërated talc, or aërated magnesian earth
(*magnesia aërata*) *magnesia alba effic.*

§ 374.

By an over-proportion of carbonic acid, the carbonat of magnesia acquires a greater degree of solubility in water. When suffered to evaporate slowly and imperceptibly, this middle salt separates from its solution in crystals of hexagonal prisms, with hexagonal pyramidal terminations, pellucid and tasteless, and efflorescing in a warm air. Their ingredients, according to *Fourcroy*, are 0,25 water, 0,25 earth of talc, and 0,50 of carbonic acid. At a moderate temperature, water dissolves no more of them than $\frac{1}{10}$ of its weight.

§ 375.

§ 375.

The fixed alkalis, and calcareous earth, exert a stronger attraction for the carbonic acid than is shewn by magnesia. But *vice versa*, the attractive power of ammoniac for that acid is weaker than that of magnesia.

§ 376.

6. *Carbonated ponderous earth*, which may be obtained by precipitating it from its solution in oxygenated muriatic acid, by the carbonat of potash (§ 343), is earthy, hardly soluble in water, and without taste. It is likewise found ready formed by nature (*Witherite*, from Dr. *Withering*, who first analyzed it. *Philos. Transact.* Vol. LXXIV). It is only with extreme difficulty that carbonat of barytes is deprived of its carbonic acid by fire alone. That which is combined by art is easier deprived of it. An excess of acid renders it more soluble in water.

Synonyma : Aërated ponderous earth (*baryta aërata, terra ponderosa aërata*).

§ 377.

The carbonic acid possesses a greater affinity with barytes than with alkalis, calcareous earth, and magnesia.

§ 378.

Carbonated Strontian-earth has an earthy texture, is not at all dissolved by water, and is destitute of taste.

taste. This middle salt is likewise procured by solution and precipitation. The solvent employed is oxygenated muriatic acid, and the precipitant is mild vegetable alkali. It is found native (*Strontianite* (§ 345) in granite rocks; and according to *Klaproth*, it has for its constituent parts 0,695 Strontian-earth, 0,300 carbonic acid, and 0,005 water. Like the natural carbonat of barytes, in a calcining fire, it parts but with difficulty with its carbonic acid; yet from an artificial combination of these two substances, the acid may be separated with less difficulty.

§ 379.

The Strontian-earth seems to have a nearer affinity with carbonic acid than the alkalis, lime and magnesia.

§ 380.

The carbonic acid does not combine with *alumine* or argillaceous earth, with the *feliceous*, *circon*, and *austral earths*. *

* This last falls off, of course. Vide note to § 349.

§ 381.

If we had a substance possessing a stronger affinity with oxygen than that which carbon has with this acidifying principle, we should then be enabled to decompose, by means of that substance, the carbonic acid, and to educe from it, or exhibit separately, the
carbonic

carbonic radical. For the present, we know no such substance. Yet Mr. Tennant and Dr. Pearson have so far succeeded, as to decompose the carbonic acid by means of double affinity (§ 50). For that purpose they exposed phosphorus with carbonat of lime, or with carbonat of soda, in a glass tube, to a strong red-heat. The result was, that carbon was formed; and, besides, phosphat of lime, or phosphat of soda. The experiment deserves well to be farther examined.

§ 382.

Is there such a thing in nature as *imperfect carbonic acid*, or *oxyd of carbon*? * I suspect its existence in the venous blood of warm-blooded animals.

* *Charcoal* seems to be such an oxyd, in the opinion of Guyton. See note to § 1163.—Ed.

Sulphur:

§ 383.

Sulphur is a simple, inflammable, acidifiable substance, of a yellow colour, insoluble in water, without odour, except by friction, or on being heated, and of a peculiar, faint taste.

§ 384.

All the brimstone, or sulphur, of commerce, is the product of nature, and merely separated by art from other extraneous matters. Besides, that now and then pure native sulphur (*sulphur nativum virgineum*) is found, it is frequently met with
5 combined

combined with metallic substances that are mineralized by it; more especially in *pyrites* (*pyritæ*), from which it is extracted by a particular kind of fusion or distillation. By another method it is also obtained, as an accessory product, on the roasting of other minerals, in which it is an ingredient. Sulphur, whatever way procured, is cast into *rolls* for sale, and then called *roll-brimstone* (*sulphur commune, citrinum*).

§ 385.

Sulphur, when heated, becomes first soft before it melts, and its fusion commences at 224° Farenh. At this degree of heat, and somewhat higher, it begins to rise in vapours, which readily kindle, as may be easily perceived in the dark. When melted sulphur, in masses of not too small a size, cools undisturbed, it readily crystallizes in the shape of thin needles. Native brimstone is mostly found in octahedral crystals, though with some variations of figure.

§ 386.

In the beginning of fusion sulphur is very fluid; but, by continuing the heat, it grows tougher, and of a red-brown colour; in which state it has already taken up a portion of oxygen, and passes with it into the state of beginning oxygenation (*oxyd of sulphur*). If, in this condition, it be poured into water, it remains as soft as wax, and yields

yields to any impression. In time it hardens again, and recovers its former consistence and colour.

§ 387.

If, to prevent inflammation, melted sulphur is debarred from the access of external air, it sublimes in vapours, adhering to the vessel in the form of slender needles, which have obtained the name of *flowers of sulphur* (*flores sulphuris*). But they are seldom quite free from sulphuric acid, which has been generated in the subliming-vessel by the decomposition of vital air.

§ 388.

If melted sulphur be exposed in open air to an increased heat, it takes fire, is entirely consumed, and burns with a flame, and an acid, suffocating vapour. The sulphur is by this combustion changed to an acid. If the heat by which burning sulphur is consumed be only weak, its flame is blue, and the acid then generated is imperfect (§ 276), very volatile, and æriform. This *imperfect sulphuric acid* we shall presently examine more closely under the name of *sulphureous acid*. But if the heat be stronger, the flame of the sulphur is white and lively, and a *perfect sulphuric acid*, in the vaporous state, is formed.

§ 389.

§ 389.

Put some threads, previously dipped in brimstone, into a capsule, or small shallow vessel made of tin, and placed in a cup floating on water; set fire to the threads, and cover the whole with an inverted glass-bell filled with vital air. A part of the sulphur only will be burnt; the oxygen gas will be decomposed, and the water will rise in the bell. The oxygen gas, though absolutely pure, is not, however, all decomposed; because, by the vapours of the acid, and the sulphureous gas thus generated, the sulphur is extinguished before it can be totally consumed. The water that has risen in the bell is now four, and reddens the tincture of litmus in the moment of contact. It is, however, impregnated with imperfect, as well as perfect, sulphuric-acid (§ 388); the former of which, if exposed to air, is, after some time, transformed into the latter.

Of the *spiritus sulphuris per campanam*.

§ 390.

According to *Berthollet*, 69 parts of sulphur absorb on combustion 31 parts of oxygen, and form with it 100 parts of concentrated sulphuric acid; that is to say, as free from water as its nature will allow. This statement, however, is not quite unquestionable. It appears from this, that the sulphuric acid is composed of sulphur and oxygen. The first takes up the latter from the vital air during

ing the heat of inflammation; thus decomposes the oxygen gas, and disengages its caloric.

Sulphuric-Acid.

§ 391.

The *fulphuric-acid*, which is also called *vitriolic-acid* (*acidum vitrioli*), is likewise frequently obtained, in great quantities, by the combustion of sulphur. In this way it is principally prepared in England; for which purpose peculiar apartments, with their insides lined all over with lead, are constructed, in order to inclose the burning sulphur. But because the sulphur would in that situation be soon extinguished, and never burn with due vivacity, about the eighth part of its weight of nitre is mingled with it to supply the vital air, without which no combustion can exist (§ 196).—Both the water at the bottom of the chamber, and also the aqueous vapours conveyed into it, imbibe the sulphuric-acid as it forms.—The weak or diluted acid thus obtained is collected and concentrated, by evaporating the superfluous water in glass-veffels.

§ 392.

Sulphuric acid, concentrated in this manner, is sold under the name of *oil of vitriol* (*oleum vitrioli*) *, and particularly with the appellation *English*, to distinguish it from another species that

is called *Saxon oil of vitriol*, or of *Nordhausen*, and which is obtained from green vitriol by distillation. Every kind of concentrated sulphuric acid, formerly found in commerce, was prepared in this last method; and it is on this account that the sulphuric-acid is generally called *vitriolic-acid*.

- * The unctuous and oleaginous appearance exhibited by this acid, and the little noise which it makes when poured from one vessel into another, together with its production from vitriol, have been assigned, for the cause of the denomination, *oil of vitriol*—Edit.

§ 393.

The vitriol itself, from which sulphuric acid is still occasionally extracted, is a metallic salt, composed of calx of iron and sulphuric acid, with or without calx of copper; it has a green colour, forms rhomboidal crystals, and excites an astringent, bitter taste. It is commonly named *green vitriol*, or *copperas*, though in its pure state it contains no copper.

The sulphuric acid of this, as well as every other kind of vitriol, derives its origin from sulphur, since this vitriol is obtained from *pyrites*, a combination of sulphur and iron, at times interspersed with copper. This pyrites, especially when roasting, decomposes, even at a moderate warmth, the oxygen gas of the atmosphere. For its sulphur absorbs oxygen from the atmosphere, and is converted into
sul-

fulphuric-acid; while the iron, on the other hand, likewise takes up part of the oxygen, is thereby oxyded, and unites with the sulphuric-acid, to form with it the metallic salt, *vitriol*. The pyrites loses by this process its hardness and metallic splendour; it is reduced to a pulverulent state, and now exhibits a harsh taste. The vitriol is lastly procured from it, ready for use, by lixiviation with water and crystallization.

§ 394.

This vitriol, or *sulphat of iron*, is separated by heat from its sulphuric acid. But as in the crystalline state it contains a large quantity of water of crystallization (§ 239), this last would greatly weaken the acid to be obtained by distillation, and the operation would unnecessarily be prolonged. The water is, for this reason, first expelled by roasting the vitriol in iron-pots till its colour is red; which when done, it is distilled from large earthen and coated retorts by a reverberatory fire (§ 59). Strongly concentrated fulphuric-acid (partly in smoke-grey vapours, partly in drops) passes then over into the receivers, which are fitted and well luted (§ 122) to the retort.

§ 395.

Oil of vitriol is a very strong acid; it burns and corrodes the skin. When pure, it has neither colour nor smell, but is very apt to turn more or

less brown, and of a sulphureous odour, by combustible, animal, and vegetable matters, as is usually the case with what is sold in the shops. Its specific gravity is from 1,800 to 2,000. It is of considerable fixity in fire, and requires a strong heat for ebullition. On account of this property a weaker oil of vitriol may be made stronger, by evaporating part of its water. Notwithstanding this, the strongest sulphuric-acid always contains some water.

§ 396.

Sulphuric-acid procured from vitriol, or the *Saxon oil of vitriol*, emits whitish grey vapours, which is not the case with the English, prepared by burning sulphur.

If the first be subjected to a gentle sand-heat, in a retort of glass having a very dry recipient luted on, a strong white smoke comes over, and is there, especially in frost, concentrated to a concrete glossy substance, which adheres to the vessel in a star-like or radiated figure; smokes exceedingly much in a warm air; produces great heat with water, forming with it diluted sulphuric-acid; attracts the moisture of the atmosphere; and liquefies, becoming thereby common sulphuric-acid. What remains of the oil of vitriol in the retort has now lost its fuming qualities; and on this volatile substance depends the property of the *Saxon oil of vitriol*

vitriol to congeal in a moderate cold to a crystalline mass, (*glacial oil of vitriol*).

By evaporating that volatile matter the oil of vitriol is deprived of this property; and pure white sulphuric-acid does not freeze, unless in a considerable cold. The volatile substance just mentioned is, according to late experiments, a combination of concentrated sulphuric with sulphureous-acid; which last we shall farther make an object of our enquiries.

§ 397.

Sulphuric-acid has a strong tendency to unite with water, and it attracts moisture from the air. Smoking oil of vitriol loses, for this reason, its fuming property, as well as its icy or glacial appearance. The sulphuric-acid produces, on being mixed with water, an instantaneous and very great heat; and for this reason, when it is to be diluted, it should be dropped little by little into the water, and not the water poured upon the acid. The sulphuric-acid thus weakened is called in the shops *Spirit of vitriol*.

§ 398.

Oil of vitriol, as it is sold, is not entirely pure sulphuric-acid. Though by boiling in open vessels it may be freed from its brown colour, and thereby made whiter; however, this is by no means competent to purify it completely, but it requires to be

rectified (§ 115). This rectification, in small quantities of about half a pound, is performed in the best way in small glass-retorts, placed in the crucible or sand-bath (§ 63). The heat applied in this case must be moderate and well regulated; and the receivers are joined without any lute.

§ 399.

With alkalis and earths the sulphuric-acid affords some peculiar combinations of the neutral and middle saline kind, called *sulphats*. Of which,

1. The *sulphat* of pot-ash, or sulphated *vegetable alkali*, shoots into small crystals, which in their regular state are a six-sided column, or prism with six-sided pyramidal terminations. Yet commonly it forms only a cohering lump or crust of salt, on whose surface the polyedral ends of the crystals protuberate. This neutral salt is of a bitterish taste, of difficult solubility in water, and requires for solution, at a moderate temperature, 12 parts by weight, and of boiling water 4,120 parts. According to *Bergman's* analysis, it contains in the crystalline state 0,40 of concentrated sulphuric-acid, 0,52 of vegetable alkali, and 0,08 of water of crystallization. The crystals are permanent in the air. By mere heat, without contact with coal, the sulphuric-acid cannot be separated from them. It melts only in a white heat.

Synonyma: *Vitriolated tartar* (*tartarus vitriolatus*); *sal de duobus*, *arcanum duplicatum*, *sal polychrestum* Glaſeri; *kali vitriolatum* of the London college.

§ 400.

The ſulphat of pot-aſh, in commerce, is not prepared by direct combination of its two principles; but is moſtly obtained accidentally, as on the decomposition of ſaltpetre by ſulphuric-acid, and the like; and ſometimes alſo on decompoſing ſulphat of iron, or vitriol, by means of pot-aſh. This neutral ſalt is but ſeldom found ready formed by nature. It is, indeed, frequently an ingredient in the aſhes of various plants, and hence met with in pot-aſhes; but it does not follow from this, that it had pre-exiſted as ſuch in the plant.

§ 401.

The vegetable alkali may be over-charged with ſulphuric-acid, if that acid be diſtilled upon it with a continued heat ſo as to render the alkali red-hot and completely dry.

§ 402.

2. The *ſulphat of ſoda*, or *ſulphated mineral alkali*, forms large, well-shaped, transparent, flattened cryſtals, of fix-sided columns, with ſtriated ſurfaces, and fix-sided pyramidal terminations. It excites a cooling, bitteriſh ſenſation on the tongue; is very ſoluble in water, requiring, at a moderate temperature,

perature, hardly three times, and of boiling water hardly its own weight, for solution. These crystals effloresce in warm dry air, falling to a white powder; and, when in a perfect state, contain, as *Bergman* states, 0,15 of mineral alkali, 0,27 of sulphuric-acid, and 0,58 of concrete water. This last causes them to melt in heat; but after the water has gone off in vapours, a white heat is required to fuse the salt in the strict sense. Nor is heat alone sufficient to expel from it the sulphuric-acid.

Synonyma: *Glauber's salt* (*sal mirabile Glauberi*) *natron vitriolatum* of the London college.

§ 403.

We certainly find this neutral salt in the fossil kingdom formed by nature; such, however, as is sold, is the product of art, and is either obtained from the crusty sediment of such brine-springs as contain *Epsum-salt*, by lixiviating that matter, and crystallizing the filtered lixivium in a freezing cold; or it is obtained in great laboratories as a profitable refuse matter, after the preparation of other salts.

§ 404.

Soda, or mineral alkali, has with the sulphuric-acid an affinity inferior to that of pot-ash; hence the sulphat of soda is decomposed by the latter in the humid way.

§ 405.

3. The *sulphat of ammoniac*, or *sulphated volatile alkali*, likewise crySTALLIZES in compressed six-sided prisms, with six-sided, more or less regular, pyramidal terminations. Its taste is of the bitterish, acrid kind; it easily dissolves in water; and, in the crystalline state, it is said by *Kirwan* to be composed of 0,40 of ammoniac, 0,42 of sulphuric-acid, and 0,18 of water. These crystals do not decay in air. By heat this neutral salt is decomposed. It has been found native in the neighbourhood of some volcanos.

Synonyma: *Glauber's secret salt of ammoniac* (*sal ammoniacum secretum Glauberi*); *vitriolic salt ammoniac* (*sal ammoniacum vitriolatum, vitriolum ammoniacale*).

§ 406.

Sulphat of ammoniac is decomposed by both the fixed alkalis, soda and pot-ash, these having a stronger attraction for the sulphuric-acid,

§ 407.

4. The combination of sulphuric-acid with lime is of very difficult solubility, so much so, that if the acid be not largely diluted with water, all the dissolved mass is directly thrown down again as a white precipitate. This *sulphat of lime* is of the same nature with *native gypsum*, or *plaster of Paris*. Art cannot produce it in such crystalline

forms, and with that transparency as nature frequently presents it to our view in the *selenitic-spar* (*lapis specularis, glacies mariæ*).

Synonyma: *Gypsum, selenites, calx-vitriolata,*

§ 408.

Sulphat of lime, to be dissolved, requires nearly 470 parts of boiling water; and this very difficult solubility is the cause why chemists are unable to exhibit their artificial sulphat of lime in so large and beautiful crystals, as are frequently presented by the natural selenitic-spar. This last, when crystallized, contains, after *Bergman*, 0,32 of calcareous earth, 0,46 of sulphuric-acid, and 0,22 of water of crystallization.

§ 409.

If gypsum be burnt, its water is driven out, and it is then called *burnt gypsum*. In this state it imbibes water, and completely crystallizes with it; and on this property depends the use of burnt gypsum for a species of mortar, called *plaster-mortar*, and in *stucco-works*.

§ 410.

Heat alone is not sufficient to expel the sulphuric-acid from gypsum; yet, when exposed to a white heat in a *crucible made of clay*, this sulphat of lime melts at last, and vitrifies.

§ 411.

§ 411.

The fulphuric-acid is not so strongly attracted by alkalis as by calcareous-earth. Sulphat of lime may, indeed, be decomposed by carbonated alkalis; but this is effected by double affinity.

§ 412.

5. Magnesian-earth is easily dissolved by fulphuric-acid, and affords with it, though but moderately diluted with water, a clear solution. By this property it is easily distinguished from calcareous-earth (§ 407). The *sulphat of magnesia*, or *bitter salt* (*sal amarum*), tastes bitter, crystallizes in regular four-sided columns, whose ends are obliquely truncated, but whose surfaces are not striated. In time, and by warmth, its crystals give out their water, and effloresce. Their constituent parts are 0,19 of magnesian-earth, 0,33 of fulphuric-acid, and 0,48 of water, as *Bergman* asserts. To effect their solution, at 50° Farenh. about twice their weight of water, but of boiling water only $\frac{2}{3}$ are necessary.

Synonyma: *Epsom salt*; *vitriolated magnesia*.

§ 413.

The fulphuric-acid cannot be disengaged from Epsom-salt, or sulphat of magnesia, by simple application of heat; yet this middle salt is decomposed

posed by the fixed alkalis, as well as by lime-water, by whose stronger affinity with sulphuric-acid this last is separated from magnesia. From the sulphat of soda this salt is readily distinguished by the turbidness which it causes if one of its crystals be dissolved in lime-water. Ammoniac decomposes but a small part of Epsom-salt; there rather arises from their mixture a triple salt (*Magnesia ammoniaco-sulphurica*),

§ 414.

The sulphat of magnesia is found native in several places, partly as a concrete saline efflorescence, partly dissolved in mineral waters, as in *bitter saline-springs*, and sometimes in other salt-springs, from the mother-water of which it is extracted with profit. Much of the bitter-salt of commerce is, however, the product of art.

§ 415.

When concentrated sulphuric-acid is poured upon magnesia recently burnt, it produces with it so strong a heat, that in a dark place it is perceived to throw out sparks.

Consult § 174, note 8.

§ 416.

6. The result of the combination of sulphuric-acid with pure argil (§ 324) is *alum*, or *sulphat of alumine* (*alumen*). This middle salt has a sweetly-austere and astringent taste; it forms octahedral crystals, of which several are bundled together in groups,

groups, in such a manner as to represent a notched or indented column. It is not very soluble in cold water, and requires more than 18 parts of it to be dissolved; of boiling water not quite two parts are necessary. Alum, perfectly pure and in the crystalline form, contains, according to *Bergman*, 0,18 of alumine or pure argil, 0,38 of sulphuric-acid, and 0,44 of water. The crystals do not easily decay in the air.

Synonyma: *Vitriolated argil*.

§ 417.

Alum, when on the fire, melts in its own water of crystallization. While this last is evaporating, the fluid alum gets tougher; froths and swells up exceedingly; and, when completely dry, it affords a loose white and very friable mass, called *burnt alum* (*alumen ustum*). By a red-heat, part of the sulphuric acid may be driven out of the alum, but not the whole.

§ 418.

Sulphat of alumine is a middle salt over-loaded with acid; and for this reason it not only reddens the tincture of litmus, but also takes up more argil, if an aqueous solution of that salt be boiled upon clay newly precipitated. The sulphat of alumine is then completely saturated, and constitutes a salt (the *glass-selenite* of *Baumé*) almost insoluble, of hardly any taste, and exhibiting cubic crystals.

§ 419.

The more sulphuric-acid is added to alum, the less it is capable of crystallizing.

§ 420.

Alum is certainly found ready formed in some mineral waters, in coal-mines, and in the lavas of volcanos; yet the greatest part of what is sold is made by art.

The most usual fossils from which it is obtained in large quantities are the *aluminous shisti*, which do not contain this salt ready formed, but are a kind of bituminous argillaceous slate, interspersed with pyrites. By the decay of this last only, the sulphuric-acid is formed, which unites with the argil to form alum, and with the calx of iron to form vitriol. If the argillaceous shisti are impregnated with much bitumen, they are first torrefied; but, if otherwise, they are simply left to moulder in the air, and afterwards are lixiviated, when this decay has reached the due degree. Such of the raw lixivium as, by its saline contents, is thought worth boiling, is evaporated in leaden pans; and then, by cooling and agitation in wooden cisterns, caused to precipitate in small crystals.

That part which remains of it, or the *mother-water*, is mixed with fresh lixivium, and again eva-

evaporated and crystallized as before. But as the aluminous lixivium always contains some green vitriol, and as, besides, by the very treatment of the lye, the iron is completely oxyded, and hence decomposed, there is in this process always an overplus of sulphuric-acid generated, which is unnecessary to saturate the alum, and which prevents it from shooting into crystals (§ 419). To remedy this inconvenience, the inspissated lye is combined with muriat of pot-ash, called *soap-maker's flux*; whereby the redundant sulphuric-acid, which prevents crystallization, is taken off, and combines with the vegetable alkali to sulphat of pot-ash; which last does not crystallize separately, but enters into the crystals of alum.

For this reason the alum of commerce is a triple salt, consisting of sulphuric-acid, argil, and pot-ash. In most cases it is also contaminated with iron. The pulverulent crystals that are obtained by the first refrigeration and agitation of the aluminous lye are styled *flour of alum*; and, being first purified by washing, made to form larger crystals by a subsequent solution, and a gradual tranquil cooling.

§ 421.

With the argillaceous shift the *fidero-pyritous-clay* agrees so far, that alum is likewise generated by the mouldering of its pyritous part, and extracted from it in the same manner as from the
alu-

aluminous shisti (§ 420). The *aluminous-rock*, from which, at *La Tolfa* near *Civita-vecchia*, the *Roman alum*, or rock-alum, is obtained, is a sulphurated clay, whose sulphur, by roasting and subsequent decay in the air, is first converted into sulphuric-acid; and this last uniting with the argil, forms the sulphat of alumine, which, by lixiviation and crystallization, is afterwards separated from extraneous matters. The crystals of this alum are covered with a reddish crust. Lastly, the *alum of Solfatara* is extracted by lixiviation from a white earth that contains alum ready formed, and originates from a black lava, which has been penetrated by sulphureous vapours.

§ 422.

Alumine, or argillaceous-earth, has not so great an affinity with sulphuric-acid as the alkalis, the calcareous, magnesian, and other earths, possess.

§ 423.

7. Ponderous earth and sulphuric acid have a very strong attraction for each other. Nevertheless, this earth affords no clear solution with that acid, even when diluted with a very great quantity of water: on the contrary, the whole compound sinks to the bottom as an insoluble sediment. This precipitate is called *sulphat of barytes*, or native *ponderous spar* (*spatum ponderosum*). It is found in crystalline shapes of great diversity; which, how-

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ever,

ever, on account of the above-mentioned insolubility, we are not able to produce by an artificial combination of these two substances. Ponderous spar is tasteless, and of a remarkably great specific gravity. In fire it parts with its water of crystallization; but the sulphuric-acid cannot be driven out from it by heat alone. When put into a crucible made of clay, and subjected to heat of such intensity as to ignite it to incandescence, this spar runs into glass.

Synonyma: *Vitriolated ponderous earth.*

§ 424.

Neither the alkalis, nor the calcareous, nor any other earth, decompose the sulphat of barytes. Of all substances, barytes possesses the nearest affinity with sulphuric-acid. The decomposition of ponderous spar by carbonat of pot-ash (§ 343) is the effect of double affinity.

§ 425.

Concentrated sulphuric-acid, assisted by heat, dissolves a portion of ponderous spar; yet the solution is decomposable by a small quantity of water.

§ 426.

8. The *sulphat of Strontian-earth* is likewise earthy, has no taste, and is scarcely soluble in 1000 times

times its weight of boiling water. If an excess of sulphuric-acid be poured upon Strontian-earth reduced to an impalpable powder, it will dissolve it totally. But as soon as a little water is added to the solution, the sulphat of Strontian-earth is again precipitated.—The attraction of Strontian-earth to sulphuric-acid seems to be not much less than that of barytes.

§ 427.

9. The *sulphat of Circon-earth* is, like the former sulphat, earthy and tasteless. It becomes soluble by a surplus of sulphuric-acid, and forms, by insensible evaporation, crystals of four-sided columns, accumulated in clusters, and possessing an astringent taste. This combination wants yet a farther investigation.

§ 428.

In the graduated arrangement of the affinities of alkalis and earths, the carbonic-acid is far exceeded by the sulphuric.—Of the reciprocal decompositions of the sulphats and carbonats, we mention in this place only that of the *sulphat of soda* by carbonat of pot-ash; that of *gypsum* by carbonated alkalis; that of *Epsom-salt* by carbonat of pot-ash; that of *ponderous spar* by carbonat of pot-ash; and, in general, the decomposition of *all the sulphats* by a solution of witherite, or carbonat of ponderous earth, in water impregnated with carbonic-acid (§ 376); which solution may, in this respect, serve as a very

sensible re-agent for discovering the sulphuric-acid, whether free or chemically combined with other substances.

Sulphureous-Acid.

§ 429.

Sulphur is capable of being oxygenated in different degrees (§ 276). In the sulphuric-acid it is saturated, or nearly saturated, with oxygen; and this is therefore to be reckoned a *perfect* acid. With a smaller portion of oxygen it exhibits an acid of a different nature, and of different properties, which ought to be regarded as an *imperfect* sulphuric-acid, and to which we give the name of *sulphureous-acid*.

Synonyma: *Pblogifticated vitriolic-acid; volatile sulphuric-acid; volatile-acid of vitriol.*

§ 430.

This sulphureous-acid is obtained by a slow combustion of sulphur, when it burns only with a blue flame. The acid generated by this process is of much less acidity than sulphuric-acid (§ 388, 391); and it is at the same time exceedingly volatile, as is apparent from the very suffocating smell issuing from the combustion, and even assuming the aerial form, if moisture is excluded.

§ 431.

Besides, this sulphureous-acid is also procured, when to sulphuric-acid a body is presented that, by its attraction for oxygen, deprives the sulphur of part of that acidifying principle, in combination with which it constituted the sulphuric-acid. If some olive-oil be brought in contact with oil of vitriol, a sulphureous-acid is immediately generated; and an odour is given out like that of burning brimstone. The same thing happens if a red-hot coal be quenched in sulphuric-acid. In both cases the acid is robbed by the carbon of part of its oxygen, and carbonic-acid gas is at the same time generated.

§ 432.

The sulphureous-acid is produced, in the purest state, upon the solution of several metals in sulphuric-acid, assisted by a boiling heat.—By way of experiment, pour together equal parts of mercury and oil of vitriol in a retort of glass, connected with the pneumatic quicksilver-trough (§ 127), and heat the mingled fluids in a sand-bath to 212° Farenh. In that heat the mercury deprives the sulphuric-acid of a portion of its oxygen, and is thereby oxyded; on the other hand, the sulphuric-acid is changed to sulphureous, and comes over into the receivers in the state of gas.

§ 433.

§ 433.

This gas has been called *sulphureous-acid gas*. It is specifically heavier than common air; one cubic Parisian inch of it weighs 1,03820 French grains, at 10° Reaum. and 28 inch. Barom. Its smell is suffocating, and its taste feebly sour; it is improper for respiration, and incapable of maintaining combustion. It cannot be confined by water, being absorbed by it; or, more properly speaking, it is decomposed by water, which takes away the sulphureous-acid from the caloric.

Synonyma: *Vitriolated air; sulphureous air.*

§ 434:

Water, that has dissolved or absorbed sulphureous-acid, is to be looked upon as liquid sulphureous-acid. It possesses a sulphureous smell, and an acidulous taste. Though at first it only reddens the syrup of violets, yet at last it totally destroys its colour. The tincture of rose-leaves, and several other pigments, lose by it all their colour. On this property rests the process of stoving silk with brimstone, for the purpose of making it white.

§ 435.

When exposed to air, the sulphureous-acid gradually takes up more oxygen from the vital air, loses thus its characteristic marks, and is converted into sulphuric-acid.

§ 436.

The neutral and middle salts, which the sulphureous-acid forms by combination with alkalis and earths, or the *sulphites*, are very strikingly different from the sulphats, or those that are formed by sulphuric-acid with the same substances. Such salts are obtained in another way, if linen or woollen cloths are soaked in an alkaline lye, and afterwards hung up extended over brimstone burning weakly and slowly; though, in this case, there is always along with the sulphureous some sulphuric-acid produced.

§ 437.

As no use is made of the sulphites in arts and trades, it will in this place be sufficient just to mention their names:

1. *Sulphite of pot-ash*, or of vegetable alkali.

Synonyma: *Stahl's sulphureous salt* (*sal neutrum sulphuris Stahliani*); *sulphureous tartar*; *volatile vitriolated tartar*.

2. *Sulphite of soda*, or of mineral alkali.
3. *Sulphite of ammoniac*, or of volatile alkali.
4. *Sulphite of lime*, or of calcareous-earth.
5. *Sulphite of magnesia*, or of magnesian earth.
6. *Sulphite of barytes*, or of ponderous earth.
7. *Sulphite of Strontian-earth*.
8. *Sulphite of alumine*, or of argil.
9. *Sulphite of Circon-earth*, or of jargon of Ceylon.

§ 438.

By sulphureous-acid the carbonic is expelled from earths and alkalis; but the first is itself disengaged from such combinations by the sulphuric as well as by most other acids.

§ 439.

Concentrated sulphuric-acid imbibes the sulphureous gas; receiving thereby, if the air find access to it, the property of emitting white fumes, and the glacial nature of the oil of vitriol of Nordhausen (§ 396).

Sulphur, with some other Substances.

§ 440.

Water and brimstone are not reciprocally acted upon by each other; nor is there any probability that sulphur alone is able to decompose water. Hence oxygen has a nearer affinity with water than with sulphur.

§ 441.

Azot and carbon have likewise no apparent attraction to sulphur. Hydrogen may enter into combination with it, as will soon be farther explained.

§ 442.

Alkalis are eminent solvents of sulphur in the humid as well as the dry way. If one part of caustic

pot-ash or of soda, and one part of sulphur, be melted in moderate heat in a covered pot, a mingled mass is obtained, which, after cooling, exhibits a liver-brown colour, and gives out no odour so long as it remains dry; but which, on being moistened, immediately sends forth a nauseous smell, like that of rotten eggs; deliquesces in the air; and is entirely dissolved by water, the solution exhibiting a yellow gold-colour. This combination has been called *liver of sulphur* (*hepar sulphuris*). Its general name is, by the new methodical nomenclature, *alkaline sulphuret*; and I shall treat here first of the *sulphuret of pot-ash*, and of the *sulphuret of soda*.

The modern French Chemists style such combinations by the general term *sulfure*, which is sufficient to discriminate it from *soufre*, by which last they translate the Latin word *sulphur*; but Dr. St. John properly substituted the word *sulphuret* for that of *sulfure*.—
Edit.

§ 443.

These combinations are also effected by boiling powdered sulphur in a lye of the caustic fixed alkali.

§ 444.

If to a solution of alkaline sulphuret in water any acid be added, the sulphur is separated by it, because of the stronger attraction of the alkali for the acid; and the sulphur is thrown down in
the

the form of a fine white powder, called *milk of sulphur* (*lac*, or *magisterium sulphuris*).—The carbonic-acid likewise separates the sulphur.

§ 445.

By pouring the acid into the alkaline sulphuret, the disgusting smell which the solution already possessed by itself becomes still stronger and truly insupportable. If dry sulphuret of alkali be employed, an effervescence takes place that cannot be perceived when the acid is added in the cold to the solution of pure alkaline sulphuret in water. The fetor mentioned before arises from the extrication and expansion of a peculiar gas, which deserves a closer consideration.

§ 446.

Take alkaline sulphuret, recently prepared and pulverized; put it into a tubulated glass-retort (§ 120) lodged in a warm sand-bath, and whose neck is joined to the pneumatic apparatus; next pour upon it some diluted sulphuric-acid, and urge the heat, by degrees, till the contents of the retort are boiling. If the hydro-pneumatic apparatus be made use of, it is advisable to put warm water in the trough.

§ 447.

The gas obtained in this manner is called *sulphurated hydrogen-gas*. It is distinguished by a very disagreeable smell; it is not respirable; it ex-

tinguishes a lighted candle immersed in it; is, however, itself inflammable, and burns after ignition, if mixed or in contact with oxygen-gas. This mixture may also be set on fire by the electric spark. If sulphurated hydrogen—, mixed with oxygen-gas, be kept in a bottle well stopped, the sulphurated hydrogen-gas will, after some time, be found decomposed, and the sides of the vessel coated with a thin lining.

Synonyma: *Hepatic gas* by *Bergman*, and *sulphureous alkaline air*.

§ 448.

Cold water absorbs the sulphurated hydrogen-gas, by degrees, and becomes possessed of its taste and smell. Water saturated with this gas is of the same nature as the *mineral sulphureous* or *hepatic waters* (*thermæ hepaticæ*); for instance, that of Aix-la Chapelle. Such waters may artificially be imitated by means of Parker's apparatus (§ 130). Exposed to the air, they become cloudy, deposit sulphur, and change the blue colour of syrup of violets to a green. Lime-water is not rendered turbid by them, provided they are not also impregnated with carbonic-acid. By boiling they are deprived of their smell and taste, and of their sulphur.

§ 449.

The bases of the gas now described are hydrogen and sulphur, or *sulphurated hydrogen*; for sulphur obtains,

obtains, by being combined with alkalis and earths, the faculty of decomposing water by attracting its oxygen, which it cannot do uncombined (§ 440). As soon, therefore, as the alkaline sulphuret encounters water, it robs it of oxygen, which, with part of the sulphur, generates sulphuric-acid, that combines with the alkali. The hydrogen, disengaged in this process, takes up another part of the sulphur, and forms with it *sulphurated hydrogen*, the basis of this gas, but which is retained by the separated portion of alkali; and it is only by the addition of an acid, and assistance of heat, that it is extricated from the alkali, and flies off in the form of gas.

Thus an *alkaline sulphuret dissolved in water* contains *sulphuret of alkali*, properly so called, besides *sulphated alkali*, and *sulphurated hydrogen*, dissolved by the alkali. When dry alkaline sulphuret is dissolved in water, a decomposition of water ensues, but no longer than until the alkaline substance is saturated with the sulphurated hydrogen. If a diluted acid be poured upon alkaline sulphuret while in the dry state, it is then the water of the acid only that has a share in the formation of this gas; and the acid acts no other part than that of extricating the basis of the gas from the alkali, by which it is dissolved.

The decomposition of *hepatic*, or *fulphurated hydrogen gas*, by vital air, may be explained by the mutual attractions of oxygen and hydrogen then taking place; whereby water is formed, and the sulphur precipitated. This is likewise the reason why water, holding fulphurated hydrogen gas in solution, lets fall the sulphur on exposure to open air.

§ 450.

When hepatic air is inclosed with caustic alkaline lye, it is rapidly and in great quantity absorbed; and sulphuret of alkali, or liver of sulphur, is again produced by this combination.

§ 451.

Alkaline sulphuret, dissolved in water, undergoes, when exposed to the atmosphere, a total decomposition. The solution, which was clear before, grows turbid; sulphur is precipitated, and the remaining lye contains at last nothing else but sulphated alkali, mingled with more or less carbonated alkali. Dry alkaline sulphuret likewise decays in open air, losing all its peculiar properties so far that, finally, nothing else remains but sulphur and sulphated alkali, together with carbonated alkali in different proportions.

§ 452.

If a cup, containing alkaline sulphuret, be placed under a bell of glass, filled with oxygen gas confined

by water, it will be found that the vital air gradually disappears, while the sulphuret of alkali endures the changes mentioned before. It was on account of this property of the alkaline sulphuret upon oxygen gas, that *Scheele* employed it for eudiometrical purposes (§ 220).

§ 453.

The ground of the reciprocal actions of liver of sulphur and vital air upon each other lies in the attraction which both sulphur and hydrogen have for oxygen; and by this it is easy to explain why the alkaline sulphuret is after some time converted into a sulphat.—Another cause of the destruction of the sulphuret of alkali in common air is to be sought for in the carbonic acid. The alkali attracts this acid, met with in the atmosphere; is by it transformed into a carbonat; and hence rendered incapable of holding sulphur in solution, which of course must precipitate.

§ 454.

When dry sulphuret of alkali is roasted over a gentle fire, and with incessant stirring, there remains at the end a whitish-grey powder, containing partly uncombined alkali, partly sulphat of alkali. By this torrefaction part of the sulphur flies off sublimed; and another part, by taking up oxygen from the atmosphere, is converted into sulphuric-acid, which combining with the alkali forms the sulphat.

§ 455.

Ammoniac also combines with sulphur. *Sulphuret of ammoniac* is obtained by the following method:—Two parts of finely pulverized quicklime are put into a dry glass-retort; upon this lime one part of sal-ammoniac, well mingled by trituration, with half a part of sulphur, is poured, and the whole well incorporated by shaking; the retort is afterwards connected with *Woulf's* apparatus (§ 123); putting, however, into its first intermediate and last receivers but a very small portion of water. Finally, the distillation is carried on in sand-bath, and with precaution.

Synonyma: *Volatile liver of sulphur* (*hepar sulphuris volatile*); *Boyle's smoking liquor* (*liquor fumans Boylei*); *Hoffman's volatile tincture of sulphur* (*tinctura sulphuris Hoffmanni*).

§ 456.

The ammoniacal sulphuret cannot be produced otherwise than in the liquid state. It possesses a yellow gold-colour, a volatile and disagreeable smell, and fumes strongly in contact with air. In other respects its properties are like the combination of sulphur with fixed alkali.

§ 457.

Lime-water dissolves likewise a small quantity of pulverized sulphur. Hence arises the *sulphuret of lime*,

lime, which is best prepared in the dry way, by mingling most intimately equal portions of chalk and powdered brimstone, and by igniting this mass throughout in a covered crucible. The carbonic-acid is driven out from the chalk by this operation, while the calcareous-earth unites with the sulphur, and remains in the vessel as a whitish powder. Towards water, acids, and vital air, this combination is disposed in the same manner as the alkaline sulphuret; and must likewise, in order to remain unaltered, be preserved in well closed vessels.

Synonyma: *Liver of lime; calcareous liver of sulphur*
(*hepar sulphuris calcareum*).

§ 458.

Sulphur may be combined in a similar way with ponderous earth; yet the sulphur does not seem to mix with pure magnesian earth so as to be soluble in water; nor does it unite in this manner with argillaceous earth.

Decomposition of the Sulphuric-Acid.

§ 459.

The transformation of sulphuric-acid into sulphureous by the means which we have mentioned above (§ 431, seq.) is an actual but incomplete decomposition of that acid. If it be intended to de-

prive it entirely of all its oxygen, and consequently to separate again the sulphur from it, it will be necessary that the carbonic-radical, by whose stronger attraction to oxygen this decomposition is chiefly to be effected, should be enabled to act on the sulphuric-acid at the temperature of ignition; and hence, also, that this acid be rendered sufficiently fixed to be capable of bearing such an intense heat. It possesses this last property when it is intimately combined with a fixed alkali, or with an earth.

§ 460.

When, therefore, equal parts of fixed alkali and of sulphat of pot-ash are most intimately blended with powdered coal, amounting in weight to one-fourth of the whole mass, and melted together in a covered crucible, an alkaline sulphuret is obtained; from which, being first dissolved in water and filtered, the sulphur may be precipitated by means of an acid.

§ 461.

In this process the ignited carbon, by virtue of its superior affinity, attracts and takes up the oxygen of the sulphuric-acid, and flies off in the character of carbonic acid gas; and the regenerated sulphur combines with the alkali, forming alkaline sulphuret, from which it is again separable by an acid. The portion of free alkali that was added serves only to promote the fusion. The superfluous
part

part of the coal employed for this operation remains behind upon solution.

Application of this process to a cheap separation of mineral alkali from Glauber's salt.

§ 462.

By a method like this the sulphuric-acid contained in gypsum and ponderous spar may be decomposed by means of charcoal-duft.

§ 463.

Upon this transformation of the sulphuric-acid into sulphur, by means of ignited charcoal, is likewise founded the generation of the *Bononian phosphorus* from ponderous spar, in which *Vincenzo Casciarolo* for the first time observed the luminous property.—For this end sulphat of barytes is first made red-hot in a crucible to render it friable; which when done, it is reduced in a stone or glass-mortar to a subtile powder, and mixed with mucilage of gum-tragacanth. Of this paste small circular plates, and other various figures, are formed. These are well dried, and exposed to red-heat between burning coals in a wind-furnace, with a good current of air, and taken out after the coals are consumed.—If these cakes be exposed for some time to day-light, they obtain the property of giving light in the dark; but they lose it again in course of time, and recover it by heat. If they be moistened
with

with water, they emit a smell resembling that of sulphurated hydrogen-gas.

§ 464.

In my opinion, it is very probable that this phosphorus is a slow combustion of the sulphur, separated in this process from the sulphuric acid that was combined with the barytes; the sulphur uniting now with this earth, and being, as it seems, in this combination, more disposed to decompose the oxygen gas than when single. The extrication of caloric is, in this case, during each instant of observation, too inconsiderable to be perceptible.

§ 465.

Canton's phosphorus is of a similar nature with the preceding, and is most successfully prepared by mingling, as accurately as possible, equal parts of pulverized oyster-shells and sulphur, and keeping them in a covered crucible for some hours in white heat. The concrete mass is afterwards broken into small pieces, and put in a dry glass-tube, which must be well corked. It will be found to give light in the dark, if previously exposed for a short time to day-light.

§ 466.

Finally, to this place belongs the *pyrophorus* of *Homburg*, which in open, and especially in moist air, inflames by itself, and burns with a sulphureous odour.

odour.—Take five parts of burnt alum (§ 417), and one part of coal finely powdered, mingling them with the utmost accuracy. With this powder fill a small earthen bottle with a narrow orifice, but no more than to about two-thirds of its capacity, and place the bottle in a pot, surrounding it with sand up to the neck. The pot must then be exposed to fire, and the heat gradually increased, until the bottle be red hot. Sulphur is now formed, subliming and burning at the aperture of the bottle with a blue flame. When that flame is no more perceived, the pyrophorus is complete. The bottle, while yet in the fire, is first closed with a stopper of clay well fitting; whereupon the pot is removed from the fire; and when the bottle is farther cooled, it is stopped very tightly with a good cork.

§ 467.

If the pyrophorus has succeeded well, and some of it be poured upon paper, it will grow hot of itself; especially when breathed upon, and then begin to catch fire spontaneously. It is totally consumed, emitting a strong sulphureous smell. When kept in bottles not well corked, it loses by time its spontaneous inflammability.

§ 468.

It is demonstrated by experiments, that alum yields pyrophorus only from the circumstance of its

containing vegetable alkali (§ 420); and that the argillaceous earth contributes nothing to that preparation.

The phenomenon exhibited by the pyrophorus may be thus accounted for. The carbonic radical decomposes in a red-heat the sulphuric acid of the sulphat of alumine, and becomes carbonic acid gas, which escapes; the sulphuric acid is converted into sulphur, which sublimes and burns. During these changes, the pot-ash, by which the alum of commerce is adulterated, fixes a part of the sulphur and retains it, especially as the calcining heat is not vehement enough totally to volatilize all the sulphur; and there remains the superfluous part of the coal that had been blended with the sulphat of alumine.

The constituent parts of the pyrophorus are consequently exceedingly dry caustic pot-ash, sulphur, carbon, and alumine.—On exposure to air, the first attracts rapidly its moisture, and is heated with it (§ 283) And this heat is sufficient to inflame the sulphur, because sulphur is already, by its own nature, when combined with alkaline substances (§ 452), by far more disposed to decompose oxygen gas. Lastly, this ignition of the sulphur in the pyrophorus is communicated to the coaly particles, that, at the beginning of its preparation, were mingled with the sulphat of alumine.

Nitric

Nitric Acid.

§ 469.

If sulphuric acid be poured upon *nitre*, an effervescence ensues, accompanied by heat, and immediate extrication of a quantity of reddish-yellow fumes, which by distillation may be condensed into a liquid. Purified dry and finely pulverized nitre is put into a glass retort, and half its weight of concentrated sulphuric acid is poured upon it, drop by drop, on account of the strong heat that arises, and stirring the matters repeatedly. A receiver is next luted to the retort, and the distillation cautiously performed, on a sand-bath previously warmed. Fumes, at first yellowish and then red, pass over into the recipient, condensing slowly to a sour, reddish-yellow fluid. A part of them condenses in the retort, and comes over in drops. The heat is kept up, until no more fumes or drops are perceived to come over.

§ 470.

The acid collected in the receivers has been formerly called, from the salt from which it is extracted, *acid of saltpetre (nitre)*; but in the new nomenclature its name is *nitric acid*. And the concentrated liquid, as described above, has obtained the appellation of *smoking spirit of nitre*

nitre (*acidum nitri fumans Glauberi*). Its specific gravity, when strongly concentrated, is 1,583. On access of air it sends forth reddish yellow fumes, which, besides, always fill the empty space of the bottles wherein it is kept. It strongly attracts moisture; grows hot by mixing with water, in which case the reddish fumes are continually increasing. When it is thus diluted with water, it first becomes green; but, on adding more water, it turns blue, and at last all colour disappears.

§ 471. *Smoking Nitric Acid*

We shall presently see that the yellow or reddish colour, and the property of emitting reddish-yellow fumes, do not belong to *perfect nitric acid*, as such, but presuppose its having undergone some modification, and are the characteristic of another less perfect nitric acid.—If, therefore, smoking nitric acid be once more distilled in a glass retort, in a sand-bath with a very gentle fire, the fuming part will rise first, and the remainder will be deprived of all its colour, and its fuming quality. In like manner is the more volatile and smoking acid parted from the remaining perfect acid (§ 470) by dilution with water; and the residual colourless diluted acid must be considered as being the pure perfect nitric acid.

§ 472.

Sometimes, instead of sulphuric acid, green vitriol calcined to redness is employed in large quantities to expel the nitric acid from nitre. Seven parts of vitriol, thus calcined, are distilled with eight parts of nitre, well dried, and reduced to fine powder, from large earthen and coated retorts, joined by luting with large recipients and adopters (§ 121), containing some water. This distillation is also performed in matrasses (§ 79) of cast-iron, provided with alembics or heads (§ 118) of clay or glass. The nitric acid of the shops, being weakened by water, is usually colourless, and not smoking. In this state it is called *aqua fortis*, or simply *spirit of nitre*. It is frequently much polluted with sulphuric and muriatic acid.

§ 473.

To free the nitric acid from the sulphuric, by which it is contaminated, the solution of barytes in nitric acid affords the most efficacious means. This solution is dropped into the nitric acid, to be purified, as long as any sulphat of barytes is precipitated (§ 423); after which the acid is again rectified. The nitric acid is only then defiled by the muriatic, when unpurified nitre has been made use of for its preparation. Of the means to clear it from this last we can only treat hereafter, when speaking of silver.

§ 474.

The residue in the retort, after distilling nitric acid from oil of vitriol and nitre (§ 470), is sulphat of potash, usually called vitriolated tartar. From this it is plain, that nitre is a neutral salt, consisting of vegetable alkali and its own peculiar acid; and that this last is less attracted by potash than sulphuric acid. But when vitriol is employed for extricating nitric acid from nitre (§ 472), the sulphat of potash is mingled with oxyd of iron; from which it may be separated by lixiviating the salt with water, and filtering the lye.

§ 475.

Nitric acid is distinguished from the sulphuric by a peculiar odour, by its volatility, and by its highly corrosive action on organic bodies. It stains the skin, hair, silk, and other animal matters, with a permanent yellow colour. Its difference from other acids is best shewn by the neutral and middle salts (*Nitrats*) which it produces.

§ 476.

1. With pot-ash, nitric acid forms the *common salt-petre*, or *nitre*; which in the new methodical nomenclature is called *nitrat of potash*; a salt shooting into prismatic, six-sided crystals of striated lateral surfaces, terminating in pyramidal summits of six surfaces; having an acrid, bitterish, cooling taste, and at a middle temperature soluble in seven

parts of water, but of boiling water requiring only a little more than its own weight for solution. Crystallized nitrat of pot-ash contains, according to *Bergman's* statement, 0,49 of potash, 0,33 of nitric acid, and 0,18 of water of crystallization. The last, however, cannot be well ascertained.

§ 477.

The crystals of nitre are permanent in the air. In heat this neutral salt liquefies and melts; and it not only loses the water of its crystals, but is totally decomposed by ignition, and its acid destroyed, as will be seen in the sequel.

Of salt-petre drops, or salt-prunellæ (nitrum tabulatum, sal prunellæ).

§ 478.

Nitrat of pot-ash is found ready formed, in great quantities, in various parts of the globe: as in the *East-Indies*, in the territory of *Molfetta in Sicily*, and in *Lower-Hungary*. Nevertheless a very considerable part of this article is artificially prepared by calcareous earth, impregnated with nitric acid, and vegetable alkali.

§ 479.

2. The *nitrat of soda* is usually called *cubic* or *rhomboidal nitre*. It is a combination of nitric acid with mineral alkali. Its crystals are rhomboids, its taste greatly resembles that of common

nitre, or nitrat of potash; it is somewhat disposed to become moist, and is in a moderate warmth soluble in two parts of water. Its component principles are, according to *Bergman*, 0,32 parts of soda, 0,43 of nitric acid, and 0,25 of water. This neutral salt is seldom found native, and no use is made of it.

§ 480.

The vegetable alkali has an affinity with nitric acid, rather nearer than that of mineral alkali.

§ 481.

3. *Nitrat of ammoniac*, or the combination of nitric acid with pure volatile alkali, forms needled crystals, has a sharp taste, readily dissolves in water, and does not decay in the air. In a red-heat, this neutral salt is totally decomposed without addition; and at the same time not only the ammoniac, but also the nitric acid, its other constituent part, undergoes decomposition, as will be proved hereafter.

Synonyma: *Nitric sal-ammoniac* (*sal ammoniacum nitrosum*); *flaming salt-petre* (*nitrum flamman*),

§ 482.

The nitrat of ammoniac is decomposed by both the fixed alkalis, in consequence of their possessing a greater affinity with nitric acid.

§ 483.

§ 483.

4. Calcareous earth is easily dissolved by nitric acid, and affords with it the *nitrat of lime*; a middle salt, of great deliquescence, of an acrid and bitter taste. A red-heat decomposes this salt, and the residual calcareous earth is possessed of the faculty of emitting light in the dark: in other words, it is the *phosphorus* of *Baldwin*, but which soon loses its phosphorescent quality.

Synonyma: *Calcareous salt-petre*, or *nitrous-lime* (*nitrum calcareum*, *calx nitrata*).

§ 484.

The two fixed alkalis attract the nitric acid more strongly than lime does; but calcareous earth has a greater affinity with that acid than pure or caustic ammoniac.

§ 485.

Nitrat of lime is found prepared by nature; and it is principally this native middle salt which is deposited on nitre-beds, and old decaying walls in the vicinity of putrefying animal substances; and from which afterwards common nitre is artificially produced (§ 478) by the addition of pot-ash.

§ 486.

5. *Nitrat of magnesia* affords likewise a very deliquescent middle salt, of a bitter and pungent taste,
and

and decomposable by fire. It has not yet been applied to any use.

Of the *magnesia niri*.

§ 487.

Pot-ash and soda completely decompose the solution of magnesian earth in perfect nitric acid; for they combine with the last, on account of their stronger affinity with it. Ammoniac, on the contrary, effects this decomposition but incompletely, and rather forms with it a triple salt (*magnesia ammoniaco-nitrica*). Lime-water instantly precipitates the magnesian earth from its solvent nitric acid, as the calcareous earth has a stronger attraction than magnesia for this acid.

§ 488.

6. The solution of pure argil in nitric acid, or *nitrat of alumine*, is, by its tendency to deliquesce, very difficultly crystallized, of a styptic or astringent taste, and decomposed by a red-heat. It has been recommended as a *corrosive*, or means of staining in the art of dying. All alkalis also, as well as lime and magnesia, decompose this middle salt.

§ 489.

7. *Nitrat of barytes*, or a combination of ponderous earth with nitric acid, admits of crystallization; and forms crystals, permanent in the air, and

and of considerably difficult solubility, having a bitter and acrid taste. Ignition decomposes it.

Synonyma: *Nitrum baryticum*, *terra ponderosa nitrata*.

§ 490.

Barytes exceeds, in its affinity with nitric acid, all alkaline substances.

§ 491.

8. Strontian earth is easily soluble in nitric acid, forming with it the middle salt, *Nitrat of Strontian*, whose crystals are not affected by the air, and are octahedral as to figure. If slips of paper are dipped into a solution of this salt, and dried again, on being lighted they burn with a beautiful purple-coloured flame.

§ 492.

The nitric-acid has a nearer affinity with all alkalis and earths than the carbonic.—As for the double affinities, we notice only, at first, the *decomposition of nitrat of lime* by the carbonats of pot-ash, of soda, of ammoniac; and, secondly, the *decomposition of the nitrats of barytes and Strontian-earth* by the same carbonated neutral salts.

§ 493.

The *sulphuric* precedes the nitric acid in the successive gradations of affinities respecting alkalis and earths. On this principle depends the expulsion

sion of nitric acid from nitre by the sulphuric (§ 474), and the application of a dissolved nitrat of barytes as a *re-agent*, to discover the presence of sulphuric acid in any fluid which it is suspected to be united with; and, therefore, as a means to purify nitric acid from any sulphuric (§ 473) with which it may be contaminated.

§ 494.

Of the double affinities between the *nitrats* and *fulphats*, I mention in this place only the *decomposition of common nitre* by Glauber's salt; the *decomposition of nitrat of lime* by the fulphats of pot-ash, of soda, of ammoniac, of magnesia, of alumine; and the decomposition of the *nitrat of barytes*, by all the fulphats that are soluble in water, whether neutral or middle salts. For this reason the nitrat of barytes is a *re-agent*, not only for free sulphuric acid (§ 493), but also for such as is combined with other substances.

Nitrous Acid.

§ 495.

The acidifiable basis of the nitric acid is capable of various degrees of oxygenation, or of receiving different portions of oxygen (§ 276); and on this account it appears in various states. I have already mentioned (§ 271) that the fuming reddish spirit
of

of nitre is not a perfect nitric acid; that by a gentle heat its smoking coloured portion may be driven out; in which case the *perfect* white and colourless nitric acid remains; and that by a similar method its smoking part may be expelled by that degree of heat which is produced on mixing this acid with water (§ 471).

§ 496.

This fuming reddish part, which is but with difficulty condensed into a liquid, which, besides, is so volatile as to form reddish vapours and clouds even at the usual temperature, and which does not possess the same degree of acidity as the perfect nitric acid, must be regarded as an *imperfect nitric acid*, and is called *nitrous acid*. A greater quantity of it is contained in the smoking spirit of nitre, in proportion as the oil of vitriol employed for its extraction from nitre has been itself more or less fuming.

§ 497.

That the acidifiable basis of *nitrous acid* is combined with less oxygen than when forming the perfect or *nitric acid*, is evident from several facts.

For example: If nitrat of pot-ash be made red-hot in a coated glass retort, and joined to the pneumatic apparatus, a great quantity of oxygen gas will come over; and, at last, if the retort be proof against melting, vapours of nitrous-acid will be

be extricated. The residuary mass of salt in the retort has an alkaline taste, but emits red fumes, and yields nitrous acid, if any of the weaker acids, as vinegar, be added, which in other circumstances would not be powerful enough to disengage the nitric acid.

It is obvious that, in this case, a portion of oxygen is expelled by the fire from the perfect nitric acid contained in nitre; and that this portion of oxygen flies off, combined with caloric, in the character of oxygen gas. Whence the acidifiable basis of that acid remains behind with the alkali, but combined with a diminished quantity of oxygen; and hence in the state of nitrous acid, until, by the continuance of heat, more or less of the basis itself is expelled.

§ 498.

From what has been said, it plainly appears why all nitrats are decomposed simply by being ignited.

§ 499.

When nitric acid is made to pass through a red-hot glass tube, it produces oxygen gas and nitrous acid.

§ 500.

To conclude, when colourless concentrated nitric acid, inclosed in a very transparent retort, connected with the pneumatic apparatus, is exposed to the rays

rays of the sun, it gives out oxygen gas, and the remaining nitric acid becomes again coloured. A dark heat, without light, does not produce these alterations.

§ 501.

Nitrous acid forms with alkalis and earths saline substances, different from those which are generated by similar combinations with nitric acid. These are called *nitrites*. Will not these salts, by exposure to open air, be again converted into nitrats? However, they are little known, and no use is made of them.

§ 502.

The nitrous acid has a much less affinity than the nitric with alkalis and earths.

Nitrous Gas.—Gaseous Oxyd of Azot.

§ 503.

All bodies of the animal and vegetable kingdom decompose nitric acid, and deprive it, by means of the radical carbon which they contain, of most of its oxygen; so that the acid now appears of a different nature, and of different habitudes with other bodies. The same is effected by a great many metals, as by copper, mercury, and iron. If nitric acid be poured upon them, heat is produced, and air-bubbles extricated, which, on the access of atmospheric air, immediately form a yellowish red cloud.

cloud. The better to judge of the changes which happen in this case, we choose the following experiment.

§ 504.

Let a small *proof-bottle* (§ 128) be filled with wire of copper or brass; let some diluted nitric acid, prepared with one part of concentrated nitric acid and three parts of water, be poured upon the wire, in such a manner that no atmospheric air remain in the vessel; and let the bottle be duly connected with the pneumatic apparatus. The metal thus exposed is dissolved by the acid with ebullition; a great quantity of air escapes through the side-aperture of the glass, which is collected in the receivers, after the first portions have been suffered to fly off.

§ 505.

The kind of air obtained by this process is called *nitrous gas*. It is colourless; shews no trace of an acid; does not redden by itself the tincture of litmus, nor render lime-water turbid; is insoluble in water, utterly unfit for respiration, and extinguishes a light brought into it. When it meets with atmospheric air, it directly abandons the aerial form, and is transformed into reddish yellow acid vapours, like those issuing from smoking spirit of nitre; and is finally converted into nitric acid, which is gradually imbibed by water. A Parisian cubic inch of this nitrous gas weighs at 10° Reaum. and 28 inch. Barom. 0,54690 French grains.

§ 506.

§ 506.

If into a cylindrical glass-vessel, holding nitrous gas confined by water, common air of the atmosphere be introduced, reddish yellow fumes are instantaneously formed; heat is produced, and the volume of the two kinds of air, taken together, is diminished; the water rises in the cylinder, and becomes diluted nitric acid. When both airs have been mixed in a just proportion, nothing else remains at last than the azotic gas of the atmospheric air (§ 197).—Usually 16 measures of this last are required to destroy completely $7\frac{1}{3}$ measures of nitrous gas.

§ 507.

If to atmospherical air, in the foregoing experiment (§ 506), pure oxygen gas be substituted, the redness and heat produced are much greater; and if both airs have been absolutely pure, and mixed in due proportion, the whole of the air that was in the cylinder disappears entirely. It is, however, difficult to obtain the nitrous and oxygen gases quite undefiled by the azotic which then remains behind.—About four measures of oxygen gas are required for $7\frac{1}{3}$ of nitrous gas.

§ 508.

The red mists formed in these two experiments (§ 506, 507) are nitrous acid, which by degrees changes to nitric acid, and is absorbed by water.

Hence, by the combination of the oxygen and nitrous gases, nitric acid is generated, and both kinds of air disappear.

§ 509.

The inference from all these experiments is, that nitrous gas contains the basis of nitric acid, which is converted into this acid by imbibing oxygen; and hence, that the metal, during its solution in nitric acid (§ 504), decomposes part of the acid by robbing it of oxygen, altering thereby its condition so much, that, at the usual temperature of our atmosphere, it no longer appears in the liquid state, but ceases to act in the capacity of an acid, and exhibits different properties. But when nitrous and oxygen gas happen to come in contact, their bases attract each other, and form again nitric acid, by dismissing their caloric.

§ 510.

The basis of nitrous gas contains, therefore, the radical of nitric acid. However, the following observations shew that it does not contain it quite pure, but always combined with a portion of oxygen, though insufficient for making an acid with that radical. Whence it farther follows, that the nitric acid is not deprived by the metal (§ 504) of the whole of its oxygen, but only of the greater part; and, consequently, that the basis of nitrous gas consists of the radical of the nitric acid, and some portion of oxygen.

§ 511.

§ 511.

But the formation of the basis of nitrous gas does not constitute the first degree of oxygenation of the radical of nitric acid; there is yet another degree below this. For if nitrous gas be left for some time in contact with wetted iron filings, or moistened alkaline sulphuret, a diminution of about two-thirds of its volume takes place, and the gas acquires properties different from its original ones. For the remaining third part of the gas is taken up by water; is neither decomposed by, nor decomposes, vital air; and produces no red fumes with it. Besides, a lighted candle burns in it with increased brightness; and a sparkling wick sunk into it is spontaneously ignited to flame. Yet burning phosphorus, sulphur, and coals, are extinguished in it, and animals are smothered. It is not affected by nitrous gas.

§ 512.

This gas, first mentioned by *Priestley* under the name of *dephlogisticated nitrous air*, is called *gaseous oxyd of azot*. During its production (§ 511) the basis of nitrous gas (§ 509, 510) is deprived of part of its oxygen, but not of the whole quantity which it contains. The radical of nitric acid, therefore, forms, in combination with a still smaller portion of oxygen, another species of gas different from the nitrous. This last may also be obtained by various other ways: for instance, by mingling

nitrat of ammoniac with about three times as much sand, and distilling it from a small retort joined to the pneumatic apparatus. Towards the end of the operation a great quantity of azotic, or nitrogen gas, comes over.

§ 513.

Hence the radical of nitric acid is capable of various degrees of oxygenation. The first and lowest degree forms the basis of the gaseous oxyd of azot (§ 512); the next constitutes the basis of nitrous gas (§ 510); the third produces nitrous acid (§ 496); and the fourth and last generates the nitric acid (§ 470).

§ 514.

Azotic gas has no influence on nitrous gas, and neither of these airs act upon each other. The nitrous gas is likewise not affected by the carbonic, hydrogen, sulphureous, and ammoniacal gases; it is, therefore, not decomposed by any of the common non-respirable kinds of air. Oxygen gas alone is capable of decomposing it; as, on the other hand, this last is itself decomposed by the nitrous gas (§ 506, 507). For this reason nitrous gas has been proposed and employed in *eudiometers*, to ascertain what quantity of oxygen gas may be contained in any given portion of atmospherical air (§ 220). This method of examining the air does not, however, afford results so constant as to be

be always depended on; though the instruments contrived by *Fontana* and *Ingenhouffz**, and the way of managing them, have arrived to very high perfection.

* See *Experiments upon Vegetables, &c.* by *John Ingenhouffz*, 8vo. Lond. 1779. Part 2, sect. 1, page 149; where the Doctor has fully explained the construction and use of *Fontana's eudiometer*.—Ed.

§ 515.

Neither carbon (§ 230), nor sulphur, decompose nitric acid in the cold; but they do it in heat, if the acid be very concentrated, though slowly and with difficulty. When combined with hydrogen, carbon, as well as sulphur, decompose the nitric acid with much greater facility. As to carbon, this is proved by vegetable and animal substances, such as sugar, oil, &c. which, even in a moderate warmth, change the nitric acid to nitrous gas. As to sulphur, this is shewn by the sulphurated hydrogen gas (§ 447), which is decomposed by concentrated nitric acid, and decomposes it in its turn. Even the sulphureous gas (§ 433) imbibes oxygen from nitric acid; and brown vitriolic acid may soon be rendered colourless by the addition of nitric acid, and by the heat arising from the mixture. Yet it would be improper to call this treatment a purification of sulphuric acid.

*Total Decomposition of Nitric Acid.**Detonation.*

§ 516.

Since charcoal, at the temperature of ignition, totally deprives the nitric acid of its oxygen, for which it exerts a stronger attraction, we can by ignited coals effect a complete decomposition of that acid, and separate its radical. But in order that nitric acid may be heated to redness, it ought to be in a fixed state, as it exists in the nitrat of pot-ash by means of the vegetable alkali.

§ 517.

Nitrat of pot-ash, which by itself melts quietly in heat, is immediately ignited with noise, if it be brought into contact with burning charcoal, or if this last be added to it when in red-hot fusion. This rapid inflammation, which is a decomposition of the nitrat of pot-ash exposed to heat with combustible matters, is called *detonation* of nitre,

§ 518.

Besides charcoal, sulphur, and phosphorus, nearly all the metals, and in general all inflammable matters, cause the nitrat of pot-ash to detonate when in the state of red-heat.

§ 519.

The combustion of inflammable bodies by detonation is performed more briskly, more rapidly, and with a brighter light, than it commonly is in atmospheric air; and it entirely resembles the combustion of these bodies in pure oxygen gas. The neutral salt is destroyed by it, and only the vegetable alkali remains; which may, indeed, be more or less altered by a new acid, the carbonic, which is generated in the process, to the production of which the combustible body gave the radical, *viz.* the carbon, and the nitric acid afforded the oxygen.

Experiments: By detonating nitrat of pot-ash with charcoal, and with sulphur.

§ 520.

If, therefore, upon nitre melted in a red-hot crucible powdered charcoal be thrown till it ceases to detonate, the remaining vegetable alkali is but partially carbonated, because part of the carbonic acid is again driven out by the ignition. That alkali is unnecessarily distinguished from pure pot-ash by the name of *fixed nitre*, or *alkaline saltpetre* (*nitrum fixum*), or by the name of *Glauber's alkahest* (*liquor nitri fixi*), after it has deliquesced in the air.

§ 521.

If, instead of charcoal, sulphur be employed in this experiment, a lively detonation likewise takes place, and the remaining alkali becomes a sulphat. By this it is plain, that in a red-heat sulphur has a nearer affinity with oxygen than azot, the radical of nitric acid.

Baumé's quick-flux.

§ 522.

The inflammation of *gun-powder* (*pulvis pyrius*) is in like manner a true detonation of nitre, by means of its coaly and sulphureous parts.

Its goodness depends on the purity of its ingredients, on their accurate and intimate incorporation, and on their due proportion to each other. Yet the proportion of these materials varies according to the use for which gun-powder is intended. Usually it is made up of 75 parts of nitre, 16 of charcoal, and from 9 to 10 of sulphur. Sulphur is necessary to cause the powder to catch fire more readily.

These ingredients are, in *gun-powder-mills*, reduced to a pulverulent state by stamping, and finely ground together, cautiously moistening the mass from time to time, to impede its flying off in dust; and, what is of the utmost consequence, to prevent

explosion. Too much moisture is hurtful, as it dissolves and washes away the nitre. The *powder-paste*, thus prepared, is afterwards *grained*; and lastly, for nicer purposes, *glazed* or polished.

§ 523.

Another remarkable composition of this kind is the *fulminating-powder*, which has this particular property, that without being confined, and even in small quantity, it deflagrates with violent explosion, if held in a spoon on ignited coals, and gradually heated, till the sulphur is set on fire. Its ingredients are three parts of nitre, two parts of dry salt of tartar (pure vegetable alkali), and one part of sulphur, very finely triturated, and well mingled together.

§ 524.

That we may be enabled to judge of what becomes of the nitric acid decomposed on the detonation of nitre (§ 519, 520), it is necessary that the operation should be performed in closed vessels, connected with the pneumatic apparatus.

A mass mingled of one part of powdered charcoal, and three parts of nitre, is the most proper for that purpose. The addition of sulphur must be avoided, as otherwise the explosion would be too violent. A portion of the above mass, moderately moistened, is put into the closed end of
a gun-

a gun-barrel, and closely rammed in. This end of the barrel is laid upon ignited charcoal, while the whole barrel is much inclined, and its aperture placed beneath the funnel of the pneumatic trough, filled with hot water.

As soon as the end of the musket, containing the materials to be detonated, becomes red-hot, the detonation begins, extending gradually throughout the whole mass, and accompanied by a vehement and copious extrication of gas.—When, after the end of the experiment, the nitre remaining in the barrel is examined, it is found totally decomposed, and in its place a carbonat of pot-ash is left, together with a greater or smaller portion of unburnt coal.—The gas that passed over, is composed of carbonic and azotic gas.

§ 525.

Since the production of carbonic acid, in this instance, cannot be explained but on the hypothesis that the carbon attracts oxygen from the nitric acid (especially as all the nitric acid entirely disappears, so much so that even the water of the trough contains no portion of it), and since a large quantity of nitrogen gas is extricated on this experiment, it follows that *azot*, or *nitrogen*, is the radical or acidifiable basis of nitric acid.

As the quantity of carbonic acid generated by this process, and also the quantity of charcoal consumed, may be ascertained, it is possible to decide upon the proportion of oxygen to nitrogen in the very concentrated nitric acid contained in the nitrat of pot-ash. For the proportion of carbon to oxygen in the carbonic acid being known (§ 225), it is, together with the quantity of the collected azotic gas, a datum from which to draw the conclusion.—According to *Lavoisier's* statement, 0,205 parts of nitrogen, and 0,795 of oxygen, are combined in nitric acid, or nearly so.

§ 526.

Hence *azot* is the acidifiable basis of nitric acid; and it assumes various forms, and is of a different nature, according as it is combined with various quantities of oxygen.—With about four parts of oxygen it constitutes the nitric acid; with about three the nitrous acid; with nearly two parts of oxygen it makes the basis of nitrous gas; and with little more than an equal part it is the basis of the gaseous oxyd of azot (§ 513).

In the *phlogistic system*, azot, or *nitrogen*, is a compound of phlogiston, and a peculiar basis of its own.

§ 527.

The above theory is confirmed by the fact, that nitrous gas, when passing through a red-hot gun-barrel, is totally changed into azotic gas, because
the

the ignited metal takes up entirely that portion of oxygen, which still remained as part of the nitrous gas.

§ 528.

By this doctrine is moreover explained: first, the total destruction, or rather decomposition, of the nitrat of ammoniac, when exposed by itself to red-heat (§ 481), and its transformation into water and nitrogen gas; as likewise the conversion of liquid ammoniac into nitrous gas, if it be made to pass, by distillation, through a tube full of native oxyd of manganese ignited to redness.

§ 529.

A synthetical proof that nitric acid is really formed by the mixture stated above, is afforded by an experiment made by Mr. *Cavendish* *. This gentleman observed, that the volume of a mixture of seven parts of oxygen gas with three parts of the azotic, and confined by an alkaline lye in a glass-tube, was diminished by frequently reiterated electric sparks; and that the lye had become a nitrat. However, it is yet a matter of question what share the electric matter had in that event.

* For farther particulars see Mr. *Cavendish's* papers in the *Phil. Trans.* vol. 75 and 78.—Ed.

§ 530.

Thus much, however, seems to be a decided, incontrovertible fact, that on the putrefaction of organic bodies, azot, one of their constituent parts, spontaneously unites with oxygen, which is yielded by water, or the atmosphere, to form by this combination nitric acid; which, in this respect, might be called a product of putrefaction. But the reason why oxygen and azotic gas produce no nitric acid by simple mixture, consists in the strong affinity of their respective bases to the caloric, with which they are united in these two gases.

§ 531.

These premises being established, it is easy to explain the theory of detonation according to the antiphlogistic system.

The nitrat of pot-ash disengages in a red-heat oxygen gas (§ 497), which causes the brisk combustion of the inflammable substances. In the temperature, which then takes place, the combustible substance seizes all the oxygen of the nitric acid, whose radical, nitrogen, is set free, and flies off in the form of azotic gas. Thus the acid of this nitrat is completely decomposed. To account for the strong heat arising on detonation, we find a sufficient cause in the great quantity of caloric, which the nitric acid of the nitrat of pot-ash still contains

contains in a fixed state, and which is not altogether employed for the formation of the gases which are then generated.

Yet the phenomena observed on detonation cannot strictly be deduced from that portion of oxygen gas, which is extricated from the nitrate of potash; they rather depend on the nitric acid itself, which in a red-heat ignites the combustible substance by its oxygen, even before this radical is disengaged in the aerial form. Lastly, it is not difficult to explain, by these observations, why, by means of nitre, the combustion may be carried on in closed vessels without any external air at all.

The cause of the dreadfully great power exerted by gun-powder, when inflamed in a confined space, lies in the extreme rapidity with which the combustion spreads throughout its mass; in the quantity of nitrogen and carbonic gases which are then so suddenly generated; in the elasticity, great beyond all computation, which that gas must receive by the immense quantity of caloric becoming free at the same time; and, finally, in the expansive power of the last in the moment of regaining its liberty.

§ 532.

In the deflagration of fulminating powder (§ 523) there is no doubt but that, on its gradual melting, fulphurated hydrogen gas (§ 447) is produced from
the

the alkaline sulphuret (by virtue of the water contained in the nitrat of pot-ash and in the alkali); or rather, that this gas, being then nascent, and at the first period of its generation, produces a fulminating air by combining with the oxygen gas, disengaged from the nitrat of pot-ash.

Muriatic Acid.

§ 533.

If upon common *culinary salt* sulphuric acid be poured, a considerable heat and ebullition instantly arise, and copious whitish fumes are extricated, of a peculiar acid and pungent taste and smell.—If these fumes be collected by distillation, and condensed with as little water as possible, an acid liquid is obtained, which is sold in the shops by the name of *smoking spirit of salt* (*spiritus salis fumans Glauberi*):

§ 534.

This four fluid is an acid of a peculiar kind, which, from the salt from which it is procured, has received the name of *muriatic acid*, *marine acid*, or *acid of sea-salt*. But because the acid thus procured, is but an imperfect acid, as will be shewn hereafter, and because its radical is susceptible of an higher degree of saturation with oxygen, I call it
muriatous

*muriatous acid** (§ 276), and make use of the expression, *muriatic acid*, to indicate that higher degree of oxygenation.

* Notwithstanding this, the term *muriatous* has, in this translation, been suppressed; and the expression *muriatic acid*, as well as its correlative term, *oxygenated muriatic acid*, constantly used. For the motives of so doing, the reader is desired to refer to the Preface.—
Editor.

§ 535.

The best way of distilling the muriatic acid is from a tubulated glass-retort lodged in a warm sand-bath, containing two parts of common salt, and connected with several collateral receivers, like the *middle bottles* of the pneumatic apparatus (§ 128), every one of them having a small quantity of water introduced. All their junctures are well luted; but the tube of the last bottle must have communication with the outer air.

When every thing is thus prepared, a third part of sulphuric acid is poured upon the two parts of salt through the tubular aperture of the retort, but very gradually, little by little; or still better, if it be suffered to drop into the retort by means of a funnel fastened to its tubular aperture, and whose inner opening may at pleasure be closed wholly, or in part only. No strong degree of heat is necessary to

to drive this acid over. Water should be put into the receivers, or else the vitriolic acid must be diluted with water, as without this precaution the muriatic acid could never be collected in the liquid form.

§ 536.

The residuum of this distillation, in the retort, is sulphat of soda. By this it appears, that the culinary salt is a neutral salt, composed of soda, and the above peculiar acid.

§ 537.

The liquid acid obtained by this process, can never, on account of the necessary addition of water, be so much concentrated as the nitric acid. It is properly colourless; and if sufficiently concentrated, emits whitish fumes on exposure to air. The yellow colour of the muriatic acid of the shops is owing to ferruginous particles. This last is prepared in a manner that cannot be approved of: viz. by distilling common salt with calcined green vitriol, and putting water into the recipients.

§ 538.

Strictly speaking, this acid on being extricated from common salt by concentrated sulphuric acid, comes over in the form of gas; which is

again decomposed by the water of the receivers imbibing its basis.

This gas is obtained by expeditiously directing the aperture of the retort underneath the funnel of the quick-silver trough (§ 126); and duly collecting the rising bubbles. It is called *muriatic acid gas*; is very sour, its basis being the muriatic acid. It is suffocating, and unfit for maintaining combustion. It is immediately imbibed by water, and this fluid becomes thereby liquid muriatic acid. Alkalis, lime-water, and the like, absorb it rapidly, and lose by this their alkaline qualities.

With atmospherical air and oxygen gas, it forms whitish clouds. If ammoniacal gas be mixed with it, and heat applied, both gases lose in a moment their aerial form, and are transformed to a concrete salt. (*Sal ammoniac*). *Muriatic acid gas* is not acted upon by carbonic and nitrogen gas; nor by pure and sulphurated hydrogen gas, nor by the sulphureous and nitrous gases; provided they be not moist.

The expression *muriatic acid gas* is taken from the New French Nomenclature:—The author calls it *muriatous gas*.—Edit.

§ 539.

The neutral and middle salts arising from muriatic acid are the following:

1. *Muriat of pot-ash*, a salt of a pure saline taste, forming cubic permanent crystals; which are soluble in three parts of cold water, contain, according to *Bergman*, 0,31 muriatic acid, 0,61 pot-ash, and 0,08 of water, and decrepitate in fire; but melt only in a red heat.

Synonyma: *Digestive salt, febrifuge salt of Sylvius.*

§ 540.

2. Of all salts the most generally known, and most abounding in nature is *muriat of soda*, or *common salt*. The primitive figure of its crystals is a cube; but the smaller cubic crystals, on evaporating the solution, usually assume the secondary form of hollow tetrahedrons. The taste of this salt is purely saline. Its crystals, if completely pure, do not decay in the air, and contain, according to *Bergman*, 0,52 of muriatic acid, 0,42 of soda, and 0,06 of water of crystallization; though the quantity of the last is obviously stated too small. At a moderate temperature these crystals require $2\frac{1}{7}$ of cold, and of boiling water $2\frac{1}{7}$ parts for solution. They cannot, therefore, be crystallized by cooling. When thrown on the fire, they decrepitate or crackle, because their water is not sufficient to dissolve the salt. In a strong red-heat this salt melts; its acid, however, cannot be expelled, nor can the soda be separated from it, by this means alone, in its pure alkaline state. In a

white-heat, this salt is entirely volatile, and on this property the manner of glazing stone-ware is founded (§336.)

§ 541.

Nature produces this neutral salt partly ready formed and undefiled as *rock-salt* (*sal gemmae*) and offers it in the mines in solid lumps; seldom crystallized; more or less transparent, and of various colours. It is found in several countries, as in England, Galicia, Hungary, Transylvania, Moldavia, &c. in strata of considerable thickness. It is also found either embodied with earths, especially gypsum, as *salt-stone*; or dissolved as in *sea-water*, or on land, in *brine-springs*; from which it is procured by evaporation; receiving thence various names of *sea-salt*, *bay-salt*, &c.

§ 542.

From the degree of solubility of the muriat of soda (§ 540), it is plain, that no brine-spring can contain more of it, than $4,184\frac{1}{2}$ ounces in the pound (of 16 ounces). The quantity of salt contained in the natural salt springs, or their *richness*, is expressed either by *lots*, viz. half-ounces of salt, which are contained in the pound, gallon, or any other fixed standard measure, or better by so much *per cent.* and is ascertained either hydrostatically by *areometers*, or chemically.—None of the known brine-springs is a solution of pure muriat of soda; but

but all of them contain, besides, some extraneous salts, and other heterogenous substances, particularly gypsum, muriat of magnesia, muriat of lime, sulphat of magnesia; all of which may contribute more or less to the impurities impairing the brine.

§ 543.

If salt-springs contain a sufficient quantity of salt, it is directly separated by evaporating the water; which process is performed in large shallow iron pans or boilers, called *stoves*.

The brine is first clarified with bullock's blood and *scummed* off. When after farther evaporation the saline pellicle appears on the surface, or if the brine begins to *grain*, the heat is so regulated, that the vapours continually break the saline crust, and thus occasion its sinking to the bottom. The precipitating salt is next taken out with perforated ladles and put into baskets, that the adhering brine may run off; and is lastly dried in well heated chambers. If this first precipitating salt be impure, it is collected by itself,

The lye remaining last in the boiler (*mother-water*) contains the not-crystallizable salts of the spring; usually some muriat of magnesia, or as is the case with ours (at *Halle* in Saxony) muriat of lime. Their accumulation in the boilers, when without cleaning them, fresh quantities of

brine are continually boiled, always makes the salt that is obtained more and more deliquescent and bitter. And the crust (called *schlot* by the workmen), which is there formed, consists of various substances; and may contain gypsum, carbonat of lime, sulphat of magnesia, and a greater or smaller portion of muriated soda.

§ 544.

If the salt-springs be too poor, and require too great an expence of fuel to extract their salt, part of the super-abundant water is evaporated by the assistance of atmospherical warmth, in particular buildings called *graduating houses*. And in order to give to the water the greatest possible surface, it is pumped up, and made to drop or trickle down through brush-wood in the form of rain; in which state the air penetrating from all quarters, greatly accelerates the evaporation, while by particular contrivances the brine is sheltered against winds and weather.

A dry and warm season is chosen for this operation. When thus sufficiently diminished, the remaining water is finally evaporated in the boilers (§ 543). The incrustations formed on the faggots and sides of the wooden pans collecting the salt-water, trickling down from the top of the building, consist chiefly of gypsum; but may also contain carbonat of lime, and carbonated oxyd of iron.—

However,

However, the salt obtained from a brine, thus graduated, is not always purer, than what is procured without that operation.

§ 545.

In some parts of Upper Germany, cavities or ditches are dug in the salt-mines, and sweet water conveyed there, for the purpose of making, in that way, artificial brines; which afterwards are evaporated by boiling.

§ 546.

From the sea-water common salt is mostly obtained by spontaneous evaporation in warmer climates, and in a warm and dry season. This is done in *salt-pits*, as they are called, or flat pieces of ground close to the sea-shore, banked round, to prevent their being overflowed at high-water, and divided into several compartments. When the crust is formed by evaporation, the workmen break it, rake it out occasionally, and let it dry in heaps. In this state it is called *bay-salt*; which is farther refined and cleared from impurities, by being again dissolved, and evaporated upon the fire. The water of the ocean is not every where equally rich in salt; towards the equator and at a great depth, it contains more than at higher latitudes, and near the surface.

* There are also some natural *salt-lakes*, as the *Feltonic* in the Russian dominions near *Saratow* and *Dmitrovsjk*.

Their salt is not different from bay-salt; except by the casual intervention of some other substances.—
Edit.

§ 547.

The muriats of soda, of whatever kind, whether obtained from rock-salt, sea-salt, or from salt-springs, are not essentially different from each other; their difference consists merely in the different adhering extraneous matters. The salt in the state in which it is commonly sold, is indeed hardly ever pure; being usually contaminated with the muriats of lime or of magnesia; and under these circumstances it is more or less disposed to grow moist and to deliquesce. Its solution is therefore rendered turbid by carbonated fixed alkali; which is never the case with pure muriat of soda.

§ 548.

Muriatic acid has a less affinity with soda, than with pot-ash; hence the muriat of soda is decomposed by the latter* *).—The process succeeds best in winter. The alkaline part of the pot-ash should equal the weight of the dry culinary salt. If common pot-ash is used, vitriolated tartar separates first (§ 643). And as the soda crystallizes only after complete refrigeration, the lading over of the lye, while yet warm, from vessel to vessel, affords an expedient to part the digestive salt (§ 539) from the mineral alkali. Those, who are
aware

aware of the quantities of carbonic acid and water contained in the carbonat of soda (§ 360), which is the result of the operation, cannot wonder that more of it is obtained, than the muriat, employed for that purpose, amounted to.

* What follows after *), the editor thought useful to transfer from the author's larger work.—Mr. *Westrumb* has likewise given an able dissertation on that subject.—Edit.

§ 549.

3. Muriatic acid, when saturated with ammoniac, forms *muriat of ammoniac* or *common sal-ammoniac*: a neutral salt, exciting a pungent, and in some manner urinous taste, shooting into double plumous or feathered crystals, which are properly an aggregate of tetrahedrons. This salt is of easy solution in water, requiring at a moderate temperature of 50° Farenh. 2,727 parts of water, and on boiling, about equal parts. The crystals continue unaltered in the air.—This salt is volatile in the fire, and may be sublimed, in loose *flowers of sal-ammoniac* if the fire be weak; but in compact cakes, if stronger.

§ 550.

Sal-ammoniac is certainly found native in various places, particularly as a volcanic product; but that of commerce is obtained by art. Till lately

no

no other factitious sal-ammoniac was known, than that which came from Egypt; where, for many centuries past, it has been prepared by sublimation from the foot of burnt camel's dung. The Egyptian muriat of ammoniac is brought to us in round convex and concave lumps or cakes, soiled in various degrees with particles of foot on their surface.—Of late it has been attempted in Europe, to combine the component principles of sal-ammoniac in a secondary way (for example, sulphat of ammoniac with muriat of soda), in such a manner, that its price may not be too great.

§ 551. *Ammoniac.*

Both the fixed alkalis immediately decompose the muriat of ammoniac, because the muriatic acid has not so great an attraction for the volatile, as for the two other alkalis, soda and pot-ash. Even simple trituration with either of them decomposes it.

English smelling bottles, (sel poignant d'Angleterre.)

§ 552.

Muriat of lime, or the combination of calcareous earth with muriatic acid, is a very deliquescent middle-salt; of a disagreeable bitter taste, not parting with its acid in the fire. It is found native in several waters and some brine-springs, as in that of *Halle*, and many render common salt deliquescent, if adhering to it (§547).

Synonyma:

Synonyma: *fixed sal-ammoniac, oil of lime (oleum calcis)*
and by some *marine selenite*.

§ 553.

As the two fixed alkalis, pot-ash and soda, have a stronger attraction for the muriatic acid, than calcareous earth is possessed of; either of them decomposes the muriat of lime.—Ammoniac, on the contrary, has a less affinity with that acid than lime; hence sal-ammoniac is decomposed by calcareous earth. On this principle depends the usual method of preparing liquid ammoniac (§ 287), or *caustic spirit of sal-ammoniac, (spiritus salis ammoniaci cum calce viva, alkali fluor.)*

To obtain it in the most commodious way, three parts of lime, just slacked in the air, are introduced into a glass retort, together with one part of sal-ammoniac; a receiver, containing one part of water, is then luted to the retort, and the distillation is cautiously performed on a sand bath. The residual mass in the retort is muriat of lime, together with some unchanged calcareous earth. It melts in a red-heat, and yields, after congealing, *Homborg's phosphorus*; which gives light in the dark, when violently struck upon, or when scratched with an iron wire; but soon loses this property in moist air.

§ 554.

5. The *muriat of magnesia* is likewise an extremely deliquescent middle-salt, of a very sharp and bitterish taste. In a red-heat it abandons its acid; but the last portions of it with greater difficulty.

Synonyma : *magnesian marine salt*.

§ 555.

Pot-ash and soda separate the magnesian earth from muriatic acid.—Ammoniac produces the same effect; but only imperfectly, forming rather with the magnesian muriat a triple salt (*ammoniocal muriat of magnesia*).—Lime-water precipitates the magnesia from the muriatic acid which held it in solution.

§ 556.

This middle salt abounds in nature, particularly in mineral waters, and salt-springs, having its share in forming their mother water (§ 543). It is likewise contained in the waters of the ocean, and is the chief cause of the bitterness of sea-water.

§ 557.

6. *Muriat of alumine*, or argil, is harsh and astringent to the taste, cannot be crystallized, and is very deliquescent. Ignition decomposes this middle-salt. All alkalis, lime-water and magnesia,

nesia, separate the aluminous earth from its combination with muriatic acid.

Synonyma :—*Argillaceous marine salt.*

§ 558.

7. *Muriat of barytes* forms a middle-salt in tabular crystals, of a bitter taste, soluble in six parts of water in a mean temperature, and not affected by the influence of the atmosphere, either to deliquesce or effloresce. A red-heat drives out its acid.

Synonyma :—*Ponderous marine salt. (Terra ponderosa salita.)*

§ 559.

Neither the fixed alkalis, nor the volatile, when pure, decompose the muriat of barytes; though the carbonated alkalis do it by means of double or intermediate affinity (§ 50). Thus also lime, magnesia and alumine, are unable to separate the acid from the barytic muriat. Hence ponderous earth has of all alkaline or earthy substances (§ 279. 300) the greatest affinity with muriatic acid; and is therefore placed directly under that acid, in the tables of elective attractions.

§ 560.

8. *Stontian-earth* is without difficulty dissolved by muriatic acid. The *muriat of Strontian-earth*, produced by this combination, forms by slow imperceptible evaporation long permanent crystals,

crystals, tasting bitter, easily soluble in water, and constituting six-sided prisms of alternate broad and narrow lateral surfaces, with three-sided pyramidal terminations. Their acid is not separated by fire. The place, which, in the list of affinities with muriatic acid, is due to Strontian-earth, is not yet exactly determined.

§ 561.

9. Circon-earth is soluble in muriatic acid; but the properties of the *muriat of circon-earth* are still unknown.

§ 562.

10. According to *Wedgwood*, the muriatic is the only acid capable of dissolving austral-earth, and requires for that purpose the assistance of boiling heat. The saturated solution of this *muriat of austral-earth* is not crystallizable, and is again decomposed by mere affusion of water; fire also expels the acid.

This section might have been spared.—See note to § 349.—Edit.

§ 563.

In the graduated arrangement of affinities, respecting alkalis and earths, the muriatic acid is by far superior to the carbonic; and all carbonats, whether neutral or middle-salts, effervesce with muriatic acid.

Of the decompositions of both kinds of neutral and middle-salts, by means of intervening double affinity, will be noticed in this place.—*First*, the decomposition of *muriat of soda* by carbonated pot-ash, and the method thence derived of obtaining carbonat of soda, though it is not an easy task to separate the muriat of pot-ash from the latter.

Secondly, the decomposition of *muriat of ammoniac* by carbonated pot-ash, and the method founded thereon of procuring carbonat of ammoniac, both in the liquid form (*spiritus salis ammoniaci tartarizatus*) and in the concrete or solid state (*sal volatile salis ammoniaci*), which is done by distilling one part of pulverized sal-ammoniac with three parts of vegetable alkali in a glass retort: adding water, if the liquid state, and omitting the water if the concrete state of the carbonated ammoniac be intended; in which last case it is properly a sublimation.

Thirdly, the decomposition of *muriat of lime* by alkine carbonats; of the *muriat of magnesia* by the carbonats of pot-ash and of soda; and the method, which depends on it, of obtaining, in a profitable way, the carbonated magnesia from the mother-lye of various salt-springs.

Lastly, the decomposition of the *muriat of barytes*, and *muriat of Strontian-earth* by carbonated alkalis, and the preparation of artificial carbonats

bonats of barytes and Strontian-earth, by this decomposition of their muriats.

* *The chemical wonder.*—If the solutions of muriat of lime, and of carbonat of pot-ash be made with as little water as possible, and added in due proportion, these two fluids coagulate to a jelly-like substance, becoming more and more solid, and at last quite hard. This is the chemical wonder mentioned by the author.—Edit.

§ 564.

As to affinity with alkalis and earths, the muriatic acid is inferior to *fulphuric acid*; as the expulsion of muriatic acid from common salt, effected by the fulphuric, sufficiently proves (§ 535). The muriat of barytes is for this reason a *re-agent*, serving to discover the presence of fulphuric acid in any fluid*.

* Hence the barytic muriat is a re-agent, of great use for purifying the muriatic acid itself from the fulphuric, which it often contains.—Edit.

Of the reciprocal decompositions of neutral and middle-salts formed by the fulphuric and muriatic acids, we mention the following: 1. The decomposition of *muriat of soda* by fulphat of ammoniac, and the preparation of sal-ammoniac and Glauber's salt thereon established (§ 550). 2. The decomposition of *muriat of soda*, by fulphat of magnesia in a freezing cold, and the cheap extraction of Glauber's salt from the incrustations

crustations formed in the boilers by such brine-springs as contain sulphat of magnesia (§ 403); and also the formation of Glauber's salt, or sulphat of soda in those salt-springs in time of frost. 3. The decomposition of *muriat of lime* by sulphat of soda, or of magnesia; and 4, The decomposition of the *muriat of barytes* by all sulphats, either of the neutral or middle kind.

§ 565.

The *nitric acid* possesses likewise a nearer affinity with alkalis and earths, than the muriatic acid. Its superiority in this respect is, however, not very great.

§ 566.

From analogy it might be concluded, that muriatic acid, like the sulphuric and nitric, is composed of a peculiar basis of its own, and oxygen. But chemists have not as yet succeeded in exhibiting the first by itself, and separating the last from it. Hence the *radical of muriatic acid* remains still unknown (§ 271). *Girtanner* thinks he has discovered, that this radical is hydrogen, and *Armet* even supposes it to be the metal zinc.

Oxygenated Muriatic Acid.

§ 567.

The radical of the muriatic acid may be combined with a still greater portion of oxygen, and

appears then in a different condition, of different qualities and dispositions towards other substances. It thus becomes a perfect acid, and has therefore been called *oxygenated muriatic acid**.

Synonym.—*Dephlogisticated marine acid*.

* The author does not approve of this appellation; he calls it simply *muriatic acid*, to distinguish it from its imperfect state, wherein he calls it *muriatous acid* (§ 534). He appeals to (277) where he asserted it to be a false supposition, that any acidifiable basis may be over-saturated with oxygen; and is in the opinion of the translator quite right in this idea. The translator, however, not presuming to command or alter the use of language, keeps to the expression of *oxygenated muriatic acid*, as adopted in this country, from the modern Nomenclature, and leaves it to the English chemists to decide upon this matter.—Ed.

§ 568.

To obtain oxygenated muriatic acid, the black oxyd of manganese is employed; which, we know, (§ 201) contains a vast quantity of oxygen, and readily gives it up to the muriatic acid.—One part of it in a pulverulent state, is put into a retort together with three parts of concentrated muriatic acid; the retort is next laid in a sand-bath, and connected with the pneumatic trough, filled with hot water; upon which a gentle heat is applied. A kind of effervescence ensues, and after the atmospheric air of the vessel has come over, an elastic fluid of a pale yellow colour is

extricated; which is caught and preserved in bottles, closed with glass stoppers fitted by grinding.

§ 569.

The expansible fluid thus obtained is not a gas, but a *vapour*, which at a temperature scarcely higher than the freezing point congeals to a concrete substance, in a pointed spicular form, and assumes again the aerial state at a raised temperature.—The elastic oxygenated muriatic acid possesses an uncommonly pungent, suffocating smell; kills in a moment all animals that are immersed in it; is absolutely and in every respect non-respirable; is gradually absorbed by water, forming with it liquid oxygenated muriatic acid. It besides does not admit of being confined by mercury; because it dissolves this metal, and can only be kept for use in bottles with stoppers of glass, well ground to fit the aperture as tightly as possible.

§ 570.

Blue vegetable pigments are not only reddened by oxygenated muriatic acid; but their colour, as well as that of every other of vegetable origin, of whatever description, is totally destroyed by it. All flowers of variegated colours, and green leaves of plants are, in time, rendered white, and discoloured by this acid. No alkali is capable

of restoring their colour when lost. Upon this property depends the use made of oxygenated muriatic acid for bleaching linen and cotton.

Berthollet has the merit of this discovery, and *Chaptal* has skillfully applied it to the restoring of old papers and sullied prints to their former whiteness. Vide his memoir on that subject, in the *Mem. of the Paris Acad.* for the year 1787—Edit.

§ 571.

A lighted wax candle continues to burn in the elastic oxygenated muriatic acid; though with a diminished and duller flame. Phosphorus, charcoal, cinnabar, grey antimonial ore, antimony, bismuth, zinc, and several other combustible bodies reduced to powder, are even spontaneously inflamed, when thrown into this elastic and warmed acid.—These inflammable substances deprive it of a part of its oxygen, and convert it into the imperfect, or muriatic acid.

§ 572.

Hydrogen gas affords with oxygenated muriatic acid, when in the elastic state, a mixture that may be set on fire. The product of the combustion is liquid muriatic acid.

§ 573.

Sulphur likewise decomposes the oxygenated muriatic acid, converting it into the simple muriatic.

riatic. For the sulphur robs the acid of part of its oxygen, and is itself converted into sulphuric acid.—Sulphurated hydrogen-gas is affected in the same manner by that elastic acid, as by vital air (§ 447, 449); sulphur is precipitated, and the perfect muriatic acid, united with the hepatic water, at the same time produced, is transformed to common muriatic acid.

§ 574.

Nitrous gas directly produces with the elastic oxygenated muriatic acid reddish fumes; and two acids, the nitrous, and the common muriatic, are formed.

§ 575.

Azotic gas seems not to act on perfect muriatic acid.—But ammoniacal gas, if that acid be warm and in an elastic state, produces with it a kind of combustion, whereby the ammoniac is decomposed, and nitrogen gas, water, and simple muriatic acid, are generated.

§ 576.

The neutral and middle-salts, or *oxygenated muriats*, which arise from the combination of alkalis and earths with perfect muriatic acid, are essentially different from the simple muriats, formed by those alkaline substances, and the common muriatic acid.

1. *Oxygenated muriat of pot-ash* forms permanent, flat crystals, assuming the shape of six-sided prisms, obliquely truncated at their ends; of a cooling saline taste; more soluble in hot, than in cold water; possessing likewise the power of oxygenated muriatic acid in being destructive of all vegetable pigments; and emitting when heated pure oxygen gas, while at the same time it is converted into common muriat of pot-ash. This neutral salt, when mingled with charcoal dust, and projected into a red hot crucible, causes a violent detonation. It does the same with sulphur. Triturated together with phosphorus, the explosion becomes very dangerous.

The experiment, made in France, for substituting this oxygenated muriat of pot-ash for nitre as an ingredient in gun-powder, has cost several lives. The strongest preparation of this kind which the translator has ever seen, was prepared by Mr. *Sandman*, who, besides the great works he carries on in partnership with Mr. *Jones* and *Alder* of Ratcliff-highway, prepares, in the most scientific manner, and greatest perfection, all the nicer and finer articles of modern chemistry, and who, though not yet sufficiently known according to his merit, yet by his genius, application, and ardent zeal for the science, fairly promises to enrich it with important discoveries: some instances of which might even now be given.—Ed.

Consult *Experiments and Observations on the Preparation, and some remarkable Properties of the Oxygenated Muriat of Pot-ash*. By Thom. Hoyle, jun. in the *Memoirs of the Manchester Society*, &c. vol. 5.—Ed.

2. *The oxygenated muriat of soda is, as to its qualities and habitudes, much alike with the former.* 3. *The oxygenated muriat of ammoniac cannot exist, according to the arguments given § 575; though Van Mons of Bruffels pretends to have made such a combination.* 4. *The oxygenated muriats, 4, of lime; 5, of magnesia; 6, of alumine; 7, of barytes; 8, of Strontian-earth; are not yet sufficiently known.*

The reader need not be reminded, that the author calls these compounds simply *muriats*, to distinguish them from those made with common muriatic acid, which he calls *muriatous*, *pot-ash*, *soda*, &c.—Edit.

§ 577.

If liquid oxygenated muriatic acid, contained in a retort made of white or crystal-glass, and connected with the pneumatic apparatus, be exposed to the sun's rays, oxygen gas is disengaged, and the residue is common muriatic acid.

§ 578.

Oxygen and muriatic acid gas (§ 538) mixed together do not produce oxygenated muriatic acid, because their union is prevented by the combination of their respective bases with the caloric.

§ 579.

The acid of the oxygenated muriat of pot-ash is driven off from its combination with the alkali, by means of sulphuric acid.

x 4

§ 580.

§ 580.

By the process for obtaining oxygenated muriatic acid (§ 568), only a part of the common muriatic acid employed is oxygenated, or converted into perfect acid: for the native oxyd of manganese gives up a part of its oxygen to that acid, which thereby is rendered elastic, and escapes in vapours; while the metal, having thus been more disoxyded, is dissolved in the remaining part of the imperfect or simple muriatic acid.

Nitro-muriatic Acid, (Aqua regia),

§ 581.

Nitric acid is likewise deprived of part of its oxygen by common muriatic acid; which last is thereby oxygenated.—If, therefore, one or two parts of strong colourless nitric acid be mixed with four parts of concentrated marine acid, a great heat and effervescence take place, and an elastic oxygenated muriatic acid is extricated. The mixture exhales also the odour peculiar to that acid, and assumes a yellow colour. In this state it contains nitrous acid, combined with oxygenated muriatic acid.

This combination has by former chemists received the name of *aqua regis*, or *regia*, and is to

to be considered as *nitro-muriatic acid*. It derives its efficacy from that portion of perfect muriatic acid which it contains; and on that account it exerts solvent powers different from those possessed by the common marine acid alone, or the nitric acid; namely, it has the power of dissolving gold.—This menstruum is also prepared by dissolving sal-ammoniac, or, in its stead, common culinary salt, in nitric acid.

Fluoric Acid, perfect and imperfect.

§ 582.

When sulphuric acid is poured upon finely levigated *fluor-spar*, a quantity of whitish fumes, possessed of a sour taste and smell, escapes; and if a plate of glass be held above these clouds, its surface is rapidly attacked by them; the glass loses its polish, becomes untransparent, and has really suffered corrosion,

§ 583.

This effect upon glass and siliceous earth is produced by no other acid, which we are at present acquainted with; and for this reason, the acid extracted from the sparry fluor by means of the sulphuric, is entitled to be considered as a distinct, peculiar acid, named *fluoric acid*.

Synonyma:

Synonyma: *Fluorous acid* by the author, because he takes it for an imperfect acid (§ 590); also *sparry acid*; *acid of fluor-spar* (*acidum fluoris mineralis*).

§ 584.

The fluoric acid may be collected by exposing fluor spar and vitriolic acid together to distillation; but it appears, from the property just mentioned, that the operation ought not to be performed in glass vessels, since the acid obtained would be contaminated with siliceous earth.

For when upon finely pulverized fluor spar an equal quantity of sulphuric acid is poured in a glass-retort, to the neck of which a receiver with water is afterwards luted, and the whole subjected to distillation on a sand-bath, the fluoric acid comes over, and is absorbed by the water. But it deposits on the sides of the receiver a pulverulent siliceous crust, which has been taken up by the acid from the glass of the retort and volatilized, but separates again as soon as the acid is absorbed and diluted by the water.

The water of the receiver, therefore, contains the absorbed fluoric acid, yet still holding a portion of siliceous earth dissolved; which is proved by saturating it with an alkali, with which the acid combines, throwing down the earth.—The residuum in the retort is gypsum, formed by the combination
of

of the fulphuric acid with the calcareous earth of the fluor-spar.

Marggraf was the first who took notice of this acid.

Scheele explained its nature, and demonstrated its difference from all other acids. *Wiegleb* proved that the earthy residue, when the process was performed in glass vessels, is of the siliceous kind. And all doubts about his opinion have been silenced; since *Scopoli* has employed gilt-silver, *Wenzel* leaden, and *Meyer* pewter-vessels, for the extraction of fluoric acid from fluor-spar.—Edit.

§ 585.

Hence, to obtain this fluoric acid in its pure state, the distillation of the experiment above described must be performed in a leaden retort and receiver.

§ 586.

With regard to smell, taste, and volatility, the fluoric acid greatly resembles the common muriatic. By distillation it cannot be obtained in a solid form without putting water in the receiver.—Unmixed with water, this acid possesses the form of gas, and is in this state expelled from the fluor-spar by the sulphuric acid; but the gas coming over is decomposed by the water of the receiver, which imbibes its basis, forming with it liquid fluoric acid.

§ 587.

§ 587.

If, therefore, on distilling fluor-spar with sulphuric acid (§ 584), the orifice of the retort be placed under the funnel of the pneumatic quick-silver-trough, the fluoric acid passes over as a permanent elastic fluid, and constitutes the *fluoric-acid gas*. This gas meeting with atmospherical air is changed to white fumes, is immediately absorbed, or rather decomposed, by water, and combines with it to form liquid fluoric acid. Its specific gravity is greater than that of common air; it is improper for respiration, and extinguishes a light brought within it. It is very sour, directly clouds lime-water, and is decomposed by it, as also by alkalis. With ammoniacal gas it unites, and forms a concrete body.

§ 588.

When this gas is distilled from a glass retort, and afterwards decomposed by the addition of water, it deposits siliceous earth. From this it is evident that the fluoric acid is capable of volatilizing, and giving the aerial form to silica.

§ 589.

From analogy with other acids, the fluoric must of course be made up of a distinct acidifiable basis and oxygen. But hitherto it has been beyond the reach of art to decompose it, or to separate its radical;

radical; which, consequently, must be ranked among the unknown substances (§ 271).

§ 590.

Various phenomena make it probable to me, that the radical of fluoric acid, as far as we are acquainted with this last, is not quite saturated with oxygen; and, consequently, that this acid must, like the muriatic, be looked upon as an *imperfect acid*. Its production in the perfect state, or completely saturated with oxygen, by means of the native manganesian oxyd, when it might be called *oxygenated fluoric acid**, deserves a farther investigation.

* The author styles it simply *fluoric acid*. The phenomena alluded to are relative to its aerial state. It does not seem that this gas is decomposed by atmospheric air, merely by attracting its moisture. There rather appears to happen in this case, though in a less degree, something similar to the alteration of nitrous gas effected by vital air (§ 508), viz. an increased oxygenation.—Edit.

§ 591.

The neutral *fluats*, or salts proceeding from the combination of fluoric acid with alkalis and earths, have never been applied to any use. It will, therefore, be sufficient to give their names:—1. *Fluat of pot-ash*. 2. *Fluat of soda*. 3. *Fluat of ammoniac*.

§ 592.

4. With calcareous earth the fluoric acid produces a compound quite insoluble in water; and if the acid be poured upon lime-water, a precipitate immediately falls down, being *fluat of lime*. Such is the natural *fluor-spar*, or simply *fluor*; which, for its entire insolubility in water, does not belong to salts, but to earths. It is found in fine cubic crystals, of various degrees of transparency, and of the most beautiful and varying colours. This spar is fusible in fire, yet without parting with its acid. While melting it dissolves other kinds of earth, and is for this property made use of as a flux in *smelting-works*, to facilitate the fusion of other matters (§ 93); whence also it has received its name. It is luminous in the dark, when heated.

§ 593.

None of the combinations of other earths with the fluoric acid is at present used either in arts or trades. Such are, 5. *Fluat of magnesia*. 6. *Fluat of barytes*. 7. *Fluat of alumine*. 8. *Fluat of Strontian-earth*.

§ 594.

The fluoric is, of all acids, the only one capable of dissolving, and even volatilizing, *siliceous earth*.—If a plate of glass be held over the vapours or smoke arising from a warmed mixture of powdered

powdered fluor-spar and sulphuric acid, its surface is shortly after attacked and corroded by them (§ 582). Hence this acid is of use for etching upon glass, and removing decayed or injured enamels from metals ornamented therewith: as watch-cases, snuff-boxes, rings, &c.

The liquid fluoric acid acts also on glass, but not so effectually as the fluoric-acid vapours. *Marggraf* first perceived this property; it was reserved to *Puymaurin* and *Klaproth* to apply it to etching upon glass.—*Beckmann* continued to improve upon this process; and *Yelin* shewed the method of etching, by this means, the glass-micrometers.—Edit.

§ 595.

Fluoric acid effervesces with and drives out the *carbonic acid* from carbonated alkalis and earths; but its affinity with those substances is not so strong as that of the *sulphuric*, *nitric*, and *muratic acids*.

Boracic Acid.—Borax.

§ 596.

The mineral acids separate from *borax*, in the humid way, an acid salt, which in every respect is characterized as a peculiar acid, and goes by the name of *boracic acid*.

Synonym: *Sedative salt* (*sal sedativum Hombergii*).

§ 597.

§ 597.

If sulphuric acid, for instance, be gradually dropped into a solution of borax in hot water till the solution acquires an acidulous taste; if the fluid be then slowly evaporated in a glass-bowl, till shining scales appear; and if, after this, it is suffered to cool, white, resplendent, saline flakes will shoot out, which, by filtering through paper, are separated from the lixivium, well washed with cold water, and dried. These are the boracic acid. When the remaining lye is farther evaporated, and treated in the same way, more such flakes are obtained. At last, *sulphat of soda* crystallizes; and for this reason the first evaporation should not be carried too far, lest that salt enter into the crystals of the boracic acid.

§ 598.

Boracic acid forms a white, scaly, glittering salt; soft to the touch; of a taste hardly acidulous, yet reddening the tincture of litmus; and of difficult solubility in cold water, requiring for solution at 50° *Farenh.* 20 parts of it; but easily dissolved by boiling water. This salt endures exposure to air; is not volatilized by fire, though by aqueous vapours it may be mechanically raised up. By a red heat it is fused into a transparent glassy mass, which is much disposed to dissolve the argillaceous earth of the crucible. By this melting it undergoes no farther change, than the loss of its water of crystallization.

lization. The boracic acid is, therefore, by its fixity in fire, greatly distinguished from all other mineral acids hitherto treated of.

§ 599.

From analogy with other acids, I am inclined to think that the boracic acid is formed by an acidifiable basis peculiar to itself, and oxygen. Yet the production of its basis, in a separate state, has hitherto frustrated all attempts; whence it is to be classed among the undiscovered principles (§ 271).

§ 600.

Immerse slips of paper into a saturated hot solution of that acid salt in water, and dry them again, they will then burn with a light yellow flame. But spirit of wine, wherein this salt has been dissolved, burns with a yellowish-green flame. This last circumstance does by no means prove, that copper is contained in boracic acid.

§ 601.

Since on preparing boracic acid, by the method stated above (§ 597) from borax by sulphuric acid, we likewise obtain sulphat of soda, it follows that the *borax* is a compound of its own acid and of soda. This substance is a salt of a bitterish alkaline taste; changing the blue syrup of violets to green; not effervescing with acids; and usually

forming six-sided prismatic crystals, two sides of which exceed the others in breadth, and which are terminated by three-sided pyramids. Of cold water it requires at 50° Farenh. 12 parts of its weight, of boiling water only 6, for solution. Its crystals are permanent in the air, and their glittering surface is but slowly dimmed by it. Exposed to moderate heat, it liquefies in its own water of crystallization, swells up very strongly, and becomes a white, solid, loose mass, of the name of *calcined borax*; no other way differing from the *crystallized*, than by the loss of the water of crystallization.—Calcined borax readily melts, as soon as it has reached the state of ignition, into a pellucid glass, which may be totally re-dissolved in water, and again crystallized.

§ 602.

The borax of commerce, with regard to its composition (§ 601), is not the produce of art, but of nature. This *native*, or *crude borax*, is called *tincal* (*tincor*, *borech*, *pounxa*), and is partly dug up in India, Thibet, and Persia; partly obtained by evaporation from the waters of some salt lakes. It was formerly at Venice, but now chiefly in Holland, refined from its adhering impurities by solution in hot water, filtration, and careful crystallization. It is then called *refined*, or *Venetian borax*.

§ 603.

The acid of borax has also been found native * in some parts of the Grand Dukedom of Tuscany; and, combined with calcareous and magnesian earths, in the gypsum of Luneburg.

- * This discovery was made in 1777 by Hoefer, on analysing the waters of the Lake *Cerchaio*, near *Monte Rotondo*; he also made borax by uniting that acid with soda. It was, besides, found in some other stagnant waters in the territory of *Sienna*; and *Mascagni* found it crystallized in the mud of those lakes.—Edit.

§ 604.

Common borax * consists, according to *Bergman*, of 0,34 of boracic acid, 0,17 of soda, and 0,49 of water. It is, however, not a perfect neutral salt (§ 293) not being quite saturated with the acid, but having an excess of alkali. On this circumstance depend its alkaline properties (§ 601), of which it may be deprived, and completely neutralized, if to a hot solution of it more boracic acid be added. 1. This *borat of soda* does not again crystallize; but exhibits, on evaporation, a clammy adhesive mass. No use is made of it.

- * As the sedative salt, or *boracic acid*, has been, and is still, employed in medicine, so is the common *borax* much used in arts, to promote fusion on soldering metals, and for other purposes.—Edit.

§ 605.

2. The *borat of pot-ash*, like common borax, takes up a surplus of alkali, and may be crystallized in four-sided columns, or parallelepipedons.—

3. The *borat of ammoniac* shoots into small rhomboidal crystals, which are decomposed by fire, and give up their alkaline part, the ammoniac.

§ 606

4. With calcareous earth the boracic acid affords a middle salt, insoluble in water, and hence without taste. This *borat of lime*, or *boracite* (combined with the next-mentioned substance), has been found native in the gypsum dug at Luneburg* in Lower Saxony, presenting cubic crystals, several or all of whose edges and corners are truncated. It is fusible in a red-heat. Lime has a stronger attraction for boracic acid, than the alkalis have.

* Of this Luneburg gypsum, or rather *borat of lime*, Dr. Crichton possesses in his exquisite collection of minerals a very fine specimen. Being himself very fond of mineralogy, he gratified his pupils with a sight of this curiosity in his *Chemical Lecture-rooms*, (now of Clifford-street). It contains magnesia, some argil and flint, and the primitive form of its crystals is doubtless a cube, not a polyhedron of 24 surfaces, as was by some imagined. When the corners and edges are truncated all around, it may receive 24 surfaces, which make it very beautiful. These crystals are so hard as to cut glass like a diamond, and strike fire plentifully with steel.—Edit.

§ 607.

5. The *borat of magnesia* is of very difficult solution in water; an excess of acid renders it soluble with greater ease. By evaporation this earthy salt yields crystalline grains, and is decomposed by lime-water.

§ 608.

6. *Borat of alumine* is, contrary to the preceding salt (§ 607), very soluble in water, and forming with it a gummy, tenacious mass, of a very styptic taste. In fire it melts into a glass. Lime, magnesia, and the alkalis, decompose the aluminous borat by depriving it of its acid, for which they have a stronger attraction.

§ 609.

7. Neither *borat of barytes*, nor, 8, *borat of Strontian-earth*, have as yet been closely examined. *Bergman* conjectures that the boracic acid possesses less affinity with barytes, than with lime.

§ 610.

Silex, or siliceous earth, is not acted upon in the humid way, not even in a boiling heat, by boracic acid. But in the dry way, if urged by fire to the degree of fusion, it is dissolved by that acid, and flows into a vitreous substance; which may be more or less decomposed by alkalis, assisted by boiling, in proportion to the quantity of boracic acid that has entered into the combination.

§ 611.

The place belonging to boracic acid, in the successive affinities of the acids with alkalis and earths, is very low. In that respect the boracic exceeds the *carbonic acid* very little; and is, therefore, inferior to all the other acids, which hitherto have been the subject of our researches.

§ 612.

Of the mutual decompositions of the borats, whether neutral or middle salts, by those of which we have before treated, I will only notice, *first*, that of soda (§ 604), or the *borax* itself, by alum, taking place in the solution of both salts together in water, forming two new compounds, namely, fulphat of soda, and borat of alumine; *secondly*, that of borax by fulphat of magnesia, or Epsom salt, from which fulphat of soda and borat of magnesia proceed; and, *thirdly*, that of borax by sal-ammoniac, forming muriat of soda, and borat of ammoniac.

CHAPTER VI.

*Constituent Parts of Vegetables.**General Examination of Vegetables.*

§ 613.

THE organic bodies offer to our view a far greater variety, with regard to their compositions, than unorganized substances. Notwithstanding this, they consist of but a small number of principles (§ 3), which, merely on account of the different reciprocal proportions in which they are combined, generate those striking and numerous variations in the nature and sensible properties of the various products.

§ 614.

It will be shewn hereafter, that by the analysis of vegetable and animal bodies, as far as it has been hitherto performed, we have as yet discovered no other radicals than those heretofore treated of.—*Carbon, hydrogen, and oxygen, are contained in*

all of them; many contain also *azot* and *phosphorus*; and these constitute in most of those bodies all their ponderable part.—*Sulphur*, *fixed alkalis*, *lime*, and *iron*, are, indeed, pretty often met with in the organic products of nature, but not in every one of them.

§ 615.

Because the proportions of these principles to each other are, from the influence of heat, air, and water, so greatly variable, we may, no doubt, easily transform into one another such of their compositions, as we chemically separate from bodies of both the vegetable and animal kingdoms. Yet we cannot produce them ourselves by combining their radicals. This can only be done by *living organs*.

§ 616.

The bodies of plants and animals are not *chemical mixtures*, but only *mechanical combinations* of other heterogeneous compounds (§ 4); and to obtain a perfect knowledge of their nature, it is required that these various mingled parts should be first singly considered, and their own composition accurately enquired into.

§ 617.

These mingled parts, whereof vegetable and animal matters consist, may be considered as their *proximate* or *immediate constituent parts* (§ 7).

They

They are separated by simple and almost mechanical operations, which cannot alter their composition; and thus prove that these compounds have, before the process, pre-existed as such in these bodies. — These proximate constituent parts have their own peculiar places assigned in organic bodies; and by this they characterize the different organization in the parts, are thus separated from each other, and shew, besides, the efficient cause of the difference in their nature. It is also obvious, that it is not every organic body that contains all those constituent parts, but each has its peculiar ones,

§ 618.

The bodies of the vegetable kingdom present the following essential proximate constituent parts (§ 617):

- | | |
|----------------------------|-----------------------------|
| 1. <i>Mucus.</i> | 12. <i>Benzoic acid.</i> |
| 2. <i>Sugar.</i> | 13. <i>Gallic acid.</i> |
| 3. <i>Starch.</i> | 14. <i>Resin.</i> |
| 4. <i>Gluten.</i> | 15. <i>Gum-resin.</i> |
| 5. <i>Albumen.</i> | 16. <i>Gum-elastic.</i> |
| 6. <i>Tartar.</i> | 17. <i>Fat-oil.</i> |
| 7. <i>Tartareous acid.</i> | 18. <i>Ethereal-oil.</i> |
| 8. <i>Salt of sorrel.</i> | 19. <i>Camphor.</i> |
| 9. <i>Oxalic acid.</i> | 20. <i>Acrid matter.</i> |
| 10. <i>Citric acid.</i> | 21. <i>Narcotic matter.</i> |
| 11. <i>Malic acid.</i> | 22. <i>Fibrous part.</i> |

§ 619.

But, before we examine each of these principles in particular, we shall first take a general survey of the habitudes and dispositions common to all plants, by analysing them in the dry way, *viz.* by fire.

§ 620.

If plants, freshly gathered, are exposed to heat not reaching the point of boiling water, they are by this freed from moisture, or *dried*.—They give out, by this process, their essential *water*, which, undoubtedly, made before one of their constituent parts; but they may also, at this temperature, be deprived of some other essential principles; as for instance, the etherial oil, the acrid and narcotic radical; and on that account they undergo some important changes respecting their powers and properties.

§ 621.

In heat, above the boiling point, vegetable substances suffer an alteration by far more remarkable. They are torrefied, or *roasted*; their mixture is conspicuously altered, and their radicals combine by the influx of caloric in different proportions, forming thus new products; as may be at once concluded from the particular smell and taste, called *empyreumatic* (*empyreuma*), which they receive by the roasting, and of which they shewed no sign before.

§ 622.

§ 622.

At a still greater heat, with proper access of air, all vegetable matters are at last ignited, and *burn* with a *flame*; leaving, after thorough *incineration*, a residuum that resists the fire, or is fixed, and always amounts to but a small quantity, in proportion to their whole mass.

§ 623.

The *soot* (*fuligo*) deposited from the flame of burning vegetables, is carbon, which, for want of a complete ingress of air into the inner part of the flame, could not be consumed; and is partly carried off mechanically along with the smoke, partly precipitated from the last. Other heterogeneous particles may, however, more or less, adhere to it, by which, consequently, its nature may be variable.

The *fluttering* and the *glossy* concrete soot of chimneys, where wood is burnt, the *soot* of oil, and that of *pine-wood*, or *lamp-black*, belong to this subject. The former kind is used by the name of *bistre*, as a brown water-colour; the lamp-black is also employed in oil and crayon-painting.—Ed.

§ 624.

All such parts as by roasting, or combustion of vegetable bodies, are dissipated, may be collected, and hence farther analysed. With this view the vegetables must be exposed to a heat of sufficient intensity,

intensity, viz. of ignition, in a retort joined with the requisite apparatus.

§ 625.

For instance: take shavings of beech-wood, introduce them into a coated earthen retort, so as to fill two-thirds of its capacity; lute to its neck a crooked glass-pipe, together with one or more intermediate bottles; taking care that all the joinings be air-tight; and direct the last conveying-tube (§ 128) beneath the funnel of the pneumatic-trough filled with hot water, or quicksilver. This done, begin with a gentle heat, increasing it gradually till the retort be red hot. At first the atmospheric air of the apparatus escapes; it is succeeded by peculiar kinds of gases and fumes, of which the first rise in the recipient placed on the shelf, at the same time that the last condense in the middle bottles by cooling.

§ 626.

An extraordinary great quantity of gas is obtained by this process. Great part of it is *carbonic acid gas*, that may be separated by lime-water, by *cream of lime* (quick-lime diffused in water to the consistence of cream), or by a solution of caustic alkali.—The remaining gas is inflammable, of a disagreeable empyreumatic smell, and possessing properties belonging to hydrogen gas; but distinguished from pure hydrogen gas by a
greater

greater specific gravity, by burning with a steadier flame, and by the particular circumstance, that on being mixed and burnt with oxygen gas, it not only yields water, but also carbonic acid; and this last, even after it had been most carefully freed from all admixture of carbonic acid gas.—It constitutes, therefore, a particular species of gas, called *carbonated hydrogen gas* *.

* Or, *heavy inflammable air*.

§ 627.

Consequently the phenomena presented by this gas evince, that hydrogen and carbon had made up its basis; and of course, also, that both these principles must have been constituent parts of the wood from which this gas was obtained.

The carbonic acid gas, which at the same time is generated, proves that, besides carbon, the wood likewise had possessed a share of oxygen.—However, the carbonic acid was not pre-existent in the wood ready formed; but its radicals, before the operation, were combined in other proportions, and with other constituent parts, forming compounds of a different kind. Only, when the intensity of heat has reached a certain degree, a part of the carbon unites with part of the oxygen to produce carbonic acid; and forms, by combining with caloric, the carbonic acid gas; while, at the same time, a part
of

of the hydrogen of the wood combines with some portion of carbon and caloric, and escapes in the form of carbonated hydrogen gas.

It is this inflammable gas which, on applying heat to wood in open air, forms the flame (§ 214) attending its combustion.

§ 628.

All plants, all their parts, and all their immediate principles or component parts, when subjected to dry distillation, afford carbonated hydrogen—and carbonic acid gas.

§ 629.

All other volatile parts that are expelled from wood by dry distillation (§ 625) are condensed into liquids by refrigeration in the middle bottles. They constitute partly an aqueous fluid, of a yellow-red colour, of an empyreumatic odour, and manifestly *sour*, which was formerly called a *spiritus*; partly they form an *oil*, of a strong empyreumatic smell, and a sharp taste. This oil floats on the aqueous *sour* fluid, and at first comes over thinner and clearer; but, towards the end, in an increased heat, it is of a darker colour, thicker consistence, more tenaceous and pitchy. Both the fluids are separable from each other by wetted filtering-paper.

§ 630.

The four fluid, obtained from wood, may be depurated from the adhering oleaginous particles by rectification (§ 115), on a sand-bath, from a glass-retort with a receiver. It may also be deprived of its superfluous water, and be thus concentrated, by other means to be mentioned hereafter, when treating of the acetic acid.—This fluid has been received in chemistry as a distinct acid, with the name of *pyro-ligneous acid*; but, if properly purified, it is not different from *acetic acid*. Its basis is a compound of carbon and hydrogen; it did not exist in wood in the state of an acid; but its constituent parts were, before the process, combined in other proportions; and even its aqueous part is the mere product of fire, being generated from the hydrogen and oxygen of the wood.

§ 631.

The *empyreumatic oil* procured by the dry distillation of wood (§ 629) may be rendered thinner by rectification, as also of a clearer colour, and more volatile; and it leaves a coaly part behind. This oil is, like the acid, a *product*, not an *educt* (§ 10); and did not pre-exist in wood. If it be burnt in oxygen gas, water and carbonic acid are formed; and the radicals of this oil are hydrogen, carbon, and some oxygen.—The quantity of carbon contained in the successive portions of this
2 oil

oil is the greater the later they come over into the receiver; and also in proportion to the intensity of the heat applied.

§ 632.

This is the place to speak of the preparation or *eliquation of tar* (*pix liquida, cedria*), performed by a kind of distillation *per descensum* (§ 124). Logs or roots of pine and Scotch fir, abounding in resin, are heated in the *tar-furnaces*; whereby the resin is partly melted, and collected by a channel contrived in the lower part of the furnace. But the resin undergoes also a partial decomposition; for which reason the wood not only gives first an attenuated clear resin, but somewhat later an acidulous water (*acid phlegm, or tar-gall*); and, finally, an empyreumatic pitchy oil, which is the *tar*, and is of a darker hue; and when inspissated upon fire becomes *black pitch*.

§ 633.

Some plants, when distilled by themselves in the dry state, afford no acid fluid; but they rather yield *carbonat of ammoniac*, partly in the concrete, partly in the fluid state; which, after being cleaned from the particles of empyreumatic oil, are quite of the same nature with any other kind of carbonated ammoniac. Such plants are *mustard-seed, onions, garlic, tobacco, atropa belladonna*, or deadly nightshade, and the *fungi*. But even the four liquor
afforded

afforded by most other plants contains ammoniac, as is evinced by the addition of fixed alkali. The foot of wood likewise yields ammoniac by distillation.

§ 634.

This ammoniac could not pre-exist ready formed in these plants; nor can it in any way be discovered in them. It is likewise only in the course of the operation, in a stronger heat, that the combination of its principles takes place (§ 291); which proves, that *azot* is likewise an ingredient in the composition of plants, and in their proximate constituent parts.

§ 635.

The residuum, after the distillation of wood (§ 625), is *charcoal*, a black, solid, friable, infusible matter, totally insoluble in water, without taste or smell, and still exhibiting the fibrous structure of the wood, from which it proceeded.—It is nothing else than that portion of carbon contained in wood, which did not meet with a sufficient quantity of oxygen to fly off with it in the form of carbonic acid, nor a sufficient portion of hydrogen to form with it carbonated hydrogen gas (§ 626); nor both together to generate, by combining with them, either empyreumatic acid, or empyreumatic oil.—It would be pure carbon, if there did not remain some other extraneous, fixed, saline, and earthy particles, that were contained in the wood, most intimately mingled with it.

§ 636.

Of this coal, or carbon, as a *simple* and *combustible substance*, I have already spoken above (§ 224, seq.); and likewise stated its habitudes with other substances examined before.

§ 637.

There is a considerable difference between different kinds of charcoal as to their texture, density, and capacity for burning, which arises partly from the nature and mixture of the bodies from which they are obtained, and also partly from the freer or more impeded access of air, that was allowed on their combustion.—These variations are the ground of the various applicability of coals for mechanical and economical purposes.

Thus *China ink* may be imitated by working up the coal of the kernels of peaches and apricots with parchment-size or ising-glass.—The *Franckfort black*, used in printing and painting, is the coal of the vine, and more frequently of the stalks and husks of grapes, and wine-lees.—The coal from the branches of the lime and hazel-trees is employed by artists to sketch their drawings.—Ed.

§ 638.

The application of charcoal, as discovered by *Lowitz*, to the purifying of saline lyes from colouring matter, (whether mucilaginous, empyreumatic, oily, resinous, gelatinous, &c.) rests on the porosity* of their structure, by which those parts are mechanically retained.

* By *Lorwitz*, and others, this faculty has been wrongly ascribed to a supposed dephlogisticating property of charcoal.—Edit.

§ 639.

The preparation of charcoal, or the *charring of coals*, is a kind of dry distillation of wood. The design of this process is to separate from it, without converting the wood into ashes, those parts which, on combustion in open air, form the smoke, soot, and flame. Hence the chief management consists in admitting no more air to the lighted wood to be charred, than what is requisite to ignite it, and to keep it in a smothering heat without being sufficient to effect a thorough combustion and incineration.

In the large way it is done in piles *upright*, or *horizontal*, by covering the pile with turf, moss, and earth, and leaving at the bottom a hole to light it up. See, among others, *L'Art du Charbonnier par du Hamel du Monceau*, fol. Paris, 1761.—Charcoal, to be good, ought to be heavy, solid, and sonorous, neither to smoke nor crackle in the fire. The best woods afford the best coal.—Edit.

§ 640.

If, on the combustion of wood, and of every other vegetable body, the free access of air be no ways checked, then that portion of radical carbon which in dry distillation remains behind, is, by taking up oxygen from the atmosphere, converted into carbonic acid, escaping in the aerial form; and there is nothing left but mere *ashes (cinis)*; a greyish powder

powder unfit for maintaining the fire; and containing, yet without cohesion, the fixed parts of the vegetable.

§ 641.

If those ashes of plants be lixiviated, or drenched with water, the lye will exhibit all the characteristic marks of the fixed alkali, which remains after the evaporation of the fluid.—Most of the plants thus treated give the *vegetable alkali*, which from them has received its name. But vegetables do not all afford it in equal quantity, and in the same purity; they, besides, give less in proportion as they have mouldered or passed into the putrescent state before incineration.—All the alkali, which by lixiviation can be procured from the ashes of plants, is impregnated, though not saturated, with carbonic acid. There may likewise, over and above the empyreumatic oleaginous particles, which give it a brownish or yellowish cast, be mingled with it other extraneous salts, or earthy matters (as sulphat and muriat of pot-ash, or siliceous and aluminous earth). This, indeed, is usually the case.

§ 642.

In order to destroy the empyreumatic oily parts contained in this salt, calcination is the best means; and to effect a complete separation of other matters (§ 641) nothing will be effectual but saturating it with carbonic acid (§ 355), and crystallizing.

§ 643.

§ 643.

Pot-ash (cineres clavellati) (§ 357) is the vegetable alkali procured from the ashes of plants, especially of the hard species of wood, by lixiviation, and subsequent evaporation of the lye.

It is not a pure vegetable alkali, but supposed to be in part only combined with carbonic acid, and hence deliquescent; for it always contains a considerable portion of sulphated vegetable alkali. While calcining, sand is now and then fraudulently added, which fuses with it, and becomes thereby soluble in water. Such siliceous pot-ash may be very sharp to the taste; but a clear solution of it in a small quantity of water will, on the addition of any acid, give a precipitate like that of the liquor of flints (§ 312), and thus discover the fraud.—Sometimes the ashes from the hearths and stoves, where wood is the fuel, are employed to procure pot-ash.

A purer vegetable alkali is obtained from the ashes of calcined *wine-lees (cendres gravelées)*; and a still purer one from tartar, which from its origin is called *salt of tartar (sal tartari)* *.

* This vegetable alkali, however pure, ought not to be confounded with the caustic vegetable alkali, deprived even of the carbonic acid, which in the new nomenclature is termed simply *pot-ash* (§ 283).—Edit.

§ 644.

Every species of vegetable alkali, if duly purified from whatever plant it might have been obtained, is of the very same nature without exception. For this reason the *salts of particular plants* (*salia herbarum*), as for example, the *salt of wormwood* (*sal absynthii*), have no preference.

Of the *Tachenic salts*.

§ 645.

The ashes which are obtained by the combustion of plants growing on shores moistened by sea-water, yield *mineral alkali* by lixiviation. The term *soda* is frequently employed to denote such kind of ashes (§ 361).—Soda, taken in this sense, is brought to Germany in masses as hard as stone, full of holes or large pores, of a blackish or grey-blue colour, intermingled with white grains, and covered with a whitish crust.

It is prepared in southern Europe, particularly on the coasts of Spain and France, from several plants, partly cultivated, partly growing spontaneously on the sea-shore; and chiefly from the species, *salsola* and *salicornia*. Those plants are dried, and then burnt in pits dug for that purpose. In these the hot embers are continually accumulated, stirring them often, as the quantity increases. At length they begin to melt,
upon

upon which they are suffered to cool. Lastly, when cold, they are broken into lumps, and taken out.—The better sort of soda is the *soude de barille*, from Alicante in Spain. An inferior kind is the *soude de varech* in Brittany, which is procured by the burning of *sea-grasses* and of *sea-tang*; both analogous to the *kelp* of Scotland.

§ 646.

The mineral alkali contained in the soda (§ 645) may be separated from earthy and other adhering parts by boiling and lixiviating those ashes; and, because it is carbonated, it admits of being crystallized. This *salt of soda* (*sal sodae, Rochettae*) is, therefore, a carbonat of mineral alkali.—There are, besides, some other extraneous salts, as Glauber's salt, and common salt, contained in the soda.

The reader will again recollect, that in the new nomenclature (adopted in this translation) by *soda*, without addition, it is not the above-mentioned ashes of sea-plants, but the mineral alkali itself, in its purest and caustic state, that is meant (§ 285).—Edit.

§ 647.

According to *Vauquelin's* latest analytical researches, the mineral alkali exists in the soda plant ready formed by nature, and also a portion of sea-salt. *Macquer* and *Poulletier de la Salle* have found in it sulphat of soda.

§ 648.

Since the sulphat of pot-ash, so frequently met with in the ashes of some species of wood (§ 643), cannot be separated from these woods before their incineration, and consequently did not pre-exist in them before combustion, it is, in my opinion, very probable that the sulphuric acid is a product (§ 10), in these ashes, and that *sulphur* is one of the constituent parts of wood, which in its combustion combines with oxygen, and is thus transformed into sulphuric acid, which uniting with the alkali forms its sulphat.

§ 649.

Yet it becomes now more and more probable, that the fixed alkalis are not simple substances; but, on the contrary, a product of vegetation. We are so much the more entitled to doubt of the simplicity of their nature, as they are no longer to be found in the residue of plants, that have undergone complete putrefaction.

§ 650.

The earthy *parts*, left after the complete lixiviation of such ashes, are of a very small amount with respect to the whole weight of the plant. Their nature is different according to the different nature of the soil, whereupon the plant grew. Yet they are as little an essential ingredient in the composition of the plant as the *iron*, that is found in those ashes.

They

They are certainly rather accidental.—To believe that the earthy parts are the chief alimentary matter of plants, was pardonable in those times only, when earth was thought to be the only principle of solidity.

The late Dr. *Ingenhous* has added to his ingenious researches on plants an excellent *Essay on the food of plants, and renovation of soils*, 4to. inserted in the papers of the London Board of Agriculture, 1796. That treatise is a valuable specimen of *applied Chemistry* and *comparative Physiology*. The Doctor intended to prove again that plants chiefly live by respirable air, and cannot live without it; that they decompose that air, keeping to themselves the carbon and azot, and giving out the oxygen combined with caloric as oxygen gas; which they do, especially about noon in sunshine, and as pure as oxygen gas obtained from the oxyd of manganese. But at night they digest more of carbon, and give out chiefly carbonic acid gas. Hence the unwholesomeness of nightly air in large thick plantations, where there is no current of air: and though, in some manner, plants feed upon azot, yet they live more upon carbon.—Dr. *Ingenhous* endeavoured, besides, to shew, 1. against Mr. *Hassenfratz*, that it is not so much carbon as carbonic acid which constitutes the aliment of plants, and whose superabundant portion they emit in the night; and, 2. that the *leaves*, and not the roots, are the principal organs by which plants imbibe the matters, requisite to the digestion of their food.—Edit.

§ 651.

Since the plants, according to what has been said before, (§ 616), are composed of heterogeneous matters

ters mechanically united, it is necessary to consider singly every one of their mingled constituent principles, with which experience has made us acquainted, and by which the fluid and solid parts are formed, if we wish to obtain a complete chemical knowledge of vegetable substances. A list, together with the names of these principles, has already been given (§ 618).

Essential Salts of Plants.

§ 652.

We call those salts *essential salts of plants* which exclusively belong to the vegetable kingdom, have as such pre-existed in the plants, and may be extracted from them by operations that do not forcibly alter their mixture.

§ 653.

These may be divided into *sour* and *sweet salts*. Of the last kind there is only one, *sugar* (*saccharum*); but of the first there exist several species. Some are *pure vegetable acids*, of which we know at present *six* essentially different: the *tartareous*, *oxalic*, *citric*, *malic*, *benzoic*, and *gallic*.—Others are a compound of pot-ash or vegetable alkali, with an excess of acid (*acidula plantarum*, *acidules* in French). *Tartar* and *salt of wood-sorrel* belong to this species.

§ 654.

§ 654.

All these vegetable acids have a compound basis. The component parts of every one are carbon and hydrogen. The variety in their habitudes and properties is caused merely by the different proportion of these principles to each other, and to oxygen in each particular acid.—There is none of them which we cannot decompose; yet we cannot compound any one.

Tartar. Tartareous Acid.

§ 655.

In casks wherein wine made of grape-juice ferments, especially of the acerb and four kind, a solid matter is deposited all around their sides, incrusting them with coherent crystals, either red or whitish-grey, according as the wine which deposited them was red or white.—This substance is called *crude tartar*.

§ 656.

This crude tartar is to be looked upon as an impure acid, and essential salt of the juice of vine-grapes, which is not originally produced by fermentation, but only separated; and is, exclusively of water, likewise contained in the juices of various other fruits. It has a sourish taste, and all the distinguishing

tinguishing marks of an acid salt; but is of difficult solution in water.

§ 657.

It may, by repeated solution, filtration, and crystallization, be freed from the feculent and colouring parts which defile it. As procured in commerce it is already purified; and this purification, in large quantities, is chiefly done at *Montpellier* in France, and at *Venice*. Such depurated tartar is sold by the name of *crystals of tartar*; and when the crystals are small, and as it were in a pulverulent state, they are called *cream of tartar*.

§ 658.

The crystals of purified tartar have no regular form. To be dissolved by water they require, according to *Spielmann*, at 50° Farenh. 160 parts of cold, but only 28 of boiling water. They are permanent in the air.

§ 659.

Tartar is, like all the proximate component parts of plants, a combustible matter. When thrown upon burning coals, it disengages an acidulous smoke of an empyreumatic smell; and, when thoroughly incinerated, it leaves the vegetable alkali (*pot-ash*) behind.

Tartar is also made use of for obtaining a very pure vegetable alkali, that has received the name of
salt

salt of tartar (§ 643). For this purpose crude tartar is wrapt up in cornets of paper, which are twined round with pack-thread, and somewhat moistened. After this the parcels are put in a wind-furnace, in alternate layers with charcoal, and ignited throughout without disturbing them. These paper-cases, with their contents, are, after cooling, pounded and lixiviated with boiling water; which being done, the strained or better filtrated lixivium is evaporated to dryness in iron pans. The pot-ash hereby obtained is only in part carbonated.

§ 660.

From this it is plain, that *tartar* is not a pure vegetable acid, but the vegetable alkali over-saturated with its acid (§ 653). For this reason it has in the new nomenclature been called *acidulous tartrite of pot ash*.

§ 661.

The acid of tartar is destructible by fire. If tartar be subjected alone to dry distillation, a great quantity of carbonated hydrogen gas (§ 626) and of carbonic acid gas (§ 226), is extricated; and, besides these, an acid fluid (*spirit of tartar*), and an empyreumatic oil (*oleum tartari fetidum*), is obtained. The remaining coal shews, even before incineration, its alkaline nature.

§ 662.

§ 662.

It would be erroneous to imagine the acid fluid, obtained by this process, to be the tartareous acid in the same state, in which it was before contained in the tartar. It was merely generated by the alteration, which the fire caused in the proportion of its principles to each other.— Besides, if duly purified, it does not present itself in the character of a distinct acid, belonging to the vegetable kingdom; notwithstanding that it has been distinguished by the name of *pyro-tartareous acid*. Its relations to other bodies are the same as those of acetic acid.—The empyreumatic oil of tartar is also, like all other oils of this kind (§ 631), a new product.

§ 663.

Like other inflammable bodies, tartar detonates with ignited nitrat of pot-ash.—Equal quantities of powdered nitre and crude tartar, mingled, and put into a red hot crucible, yield pot-ash after detonation. This pot-ash owes its existence to both bodies employed; has by former chemists been called *white flux*; and differs in no manner from any other good, and but partially carbonated vegetable alkali.—If to one part of nitrat of pot-ash, three parts of crude tartar be added, a portion of the coal afforded by the later, remains united with the alkali, giving it a black colour,

colour, and both together constitute the *black flux*.

The name *flux* is given to this combination; because it is added to promote the fusion of earths and metals.—
Edit.

§ 664.

The superabundant acid of purified tartar may be fully saturated with pot-ash in the humid way; if to a hot solution of vegetable alkali as much of pulverized tartar be added, as is necessary, so that neither the acid nor the alkali predominates.

By this combination a neutral salt, the *tartrite of pot-ash* is obtained, which, in the shops, is barbarously termed *tartarized tartar* (*tartarus tartarizatus*)*. This salt may be crystallized; but for common use, the lye, thus combined, is totally evaporated to dryness. It is much more soluble in water than crystals or cream of tartar (§ 657), requiring at 50° Farenh. only 2,264 parts, and at the temperature of boiling, scarcely equal parts of water to be dissolved. By fire this neutral salt is decomposed. It burns first to a spongy coal; but when calcined to whiteness, it leaves the pot-ash behind.

* Also called *sal vegetabile*; and most improperly *tartarus solubilis*, because this appellation likewise suits the combination of tartar with other alkalis.—Edit.

§ 665.

Purified tartar, saturated with soda, forms a triple salt, called in the shops *seignette-salt** (*sal polychrestum de Seignette, sal Rupellense* or *Rochelle*); which shoots into well-shaped crystals, whose figure is very variable. This salt is entirely, and with ease, soluble in water. Its crystals are permanent. A calcining heat destroys it.

* This combination has in the London Pharmacopœia obtained the name of *natron tartarizatum*. It is used as an addition to cathartics of the resinous kind, &c.
—Edit.

§ 666.

With ammoniac the purified tartar affords likewise a triple salt, which has been called *soluble tartar*; also *tartareous sal-ammoniac* (*tartarus solubilis, ammoniacalis*). It forms crystals of four-sided columns with terminations obliquely truncated, and in opposite directions. It easily dissolves in water. Fixed alkalis decompose it in the humid way; and by fire it is likewise destroyed in such a manner, that merely the pot-ash of the tartar is left.

§ 667.

If purified tartar and quick-lime be boiled together in water, the result is a caustic lye of pot-ash. All the acid of the tartar combines with the calcareous earth, and produces with it
the

the *tartrite of lime*, which is almost insoluble in water. If, instead of burnt lime, crude calcareous earth, *viz.* carbonat of lime, be boiled with tartar and water, the whole of the tartareous acid is not separated from the alkali; but only its predominating and redundant part unites with the chalk. The lixivium yields tartrite of pot-ash (§ 664), and some tartrite of lime.

§ 668.

Sulphuric acid has a stronger affinity with calcareous earth than the acid of tartar; this last, therefore, may be separated from the tartrite of lime, by the sulphuric acid in the humid way. This has induced chemists to attempt the producing of *tartareous acid* itself in a state of purity.

This vegetable acid has also been called *essential salt of tartar*.

§ 669.

To prepare this acid, 10 parts of pulverized and purified acidulous tartrite of pot-ash (§ 660) are boiled with a sufficient quantity of water in a pewter vessel. Dry, finely powdered, and elutriated chalk is then put in by small quantities at a time, until no more effervescence ensues. Tartrite of lime or *tartareous selenite* will precipitate; and the lye standing upon the sediment is tartrite of pot-ash. This lixivium must be de-

canted, and may be crystallized after filtration, or simply evaporated (§ 664).

The earthy salt, which formed the precipitate, is first carefully lixiviated with water, and put into a matrafs. Thirty parts of diluted sulphuric acid, made by mixing 3 parts of the concentrated acid with 27 of water, are then poured upon it. The whole is left in digestion for at least 12 hours, with a gentle heat. After which the clear liquid is decanted, and the residuum, which, by the union of the sulphuric acid with lime, forms gypsum (§ 407), is pressed and washed with *cold* water, to get out the adhering acid, which is added to the clear liquor of the preceding decantation, and is the tartareous acid. It is next filtered, and gently evaporated in flat porcelain or glass vessels; during which operation it deposits gypsum, which, from time to time, must be separated.

The evaporation is to be carried on to the consistence of a thin syrup. And when the clear tartareous acid is then left to a continued, slow, and imperceptible evaporation, it crystallizes.

Chemistry is indebted to *Scheele* for this method. To be assured that no vitriolic acid is contained in the liquor, a solution of sugar of lead is added to a small portion of it. The white precipitate, formed by this, will be dissolved on the addition of nitric acid, if it be merely tartarite of lead, and there
be

be no sulphat of lead formed by the vitriolic acid.—
 The translator cannot recommend Schiller's method in the Chemical Annals of Crell, 1787, which consists in simply boiling 1 lb of cream of tartar, with 6 lb of water, and adding $\frac{1}{4}$ lb of concentrated sulphuric acid. It seems more simple indeed, and is apparently true in theory; yet the translator has, on several attempts, as little succeeded as others. Instead of vitriolated tartar, and tartareous acid, there is always only simple tartar produced, though somewhat sulphated.—Edit.

§ 670.

This essential salt of tartar forms tabular, and sometimes spear-shaped crystals, bundled together in glandular groups. Their taste is exceedingly sour; they are not altered by the air; but they are easily dissolved in water, and not volatilized by boiling heat.

§ 671.

Tartareous acid is destroyed by fire, and consumed. By dry distillation it gives the same products as tartar: namely, carbonated hydrogen gas, carbonic acid gas, a sour phlegm which is analogous to acetic acid, and an empyreumatic oil. There remains some coal in the retort.

§ 672.

Hence the radical of tartareous acid consists of hydrogen and carbon. Both together, united with a certain portion of oxygen, form this acid; which on account of its peculiar properties is to be

considered as a distinct acid. It is doubtless capable of receiving a greater share of oxygen, and of different proportions, in the component parts of its basis.—But it is then no longer tartareous acid; but is converted into another species of vegetable acid, as is proved even by dry distillation (§ 671).

§ 673.

Tartareous acid boiled with the sulphuric, is, for the most part, converted into acetic acid. The sulphuric is changed into sulphureous acid by this process; and carbonic acid gas is generated at the same time.

§ 674.

Concentrated nitric acid is likewise decomposed in heat by the acid of tartar; nitrous gas, acetic and carbonic acids are then produced.

§ 675.

1. If tartareous acid be completely saturated with pot-ash, the same neutral salt is obtained, as by combining tartar with pot-ash, *viz.* *tartrite of pot-ash*, or the officinal *tartarus tartarizatus* (§ 664). If less of the vegetable alkali be added to tartareous acid dissolved in water, it produces tartar, called *regenerated tartar*, which in consequence of its difficult solution precipitates, and this proves, that the tartareous acid

acid pre-existed as such in the tartar. Tartrite of pot-ash may be again converted into tartar, by adding tartareous acid to a solution of the former.

§ 676.

No use is made of the combinations of pure tartareous acid with other alkalis, and alkaline earths. Such are, 2. *Tartrite of soda*. 3. *Tartrite of ammoniac*. 4. *Tartrite of lime*; the use of which last in the preparation of tartareous acid has been mentioned before (§ 668); and besides, the *tartrites* 5. of *magnesia*, 6. of *alumine*, 7. of *barytes*, and 8. of *Strontian-earth*.

§ 677.

The successive series of affinities of alkalis and earths with tartareous acid, is as follows: lime, to which it has the strongest affinity, then barytes, magnesia, pot-ash, soda, ammoniac, and lastly, alumine.

§ 678.

The lixivium remaining from the decomposition of tartar, or of the tartareous neutral-salts by quick-lime, has the particular property of continuing clear and bright, while cold; but growing milky on being heated, whether in open or closed vessels. It also acquires this turbidness by being largely diluted with water; and becomes clear and pellucid by cooling.

§ 679.

With regard to affinity with alkalis and earths, the tartareous acid is by far superior to the *carbonic*; but is greatly exceeded by the *fulphuric*. Of the mutual decompositions of the sulphats and tartrites, we only take notice, in this place, of the tartrite of pot-ash decomposed by sulphat of soda. In order to make the experiment, let six parts of purified tartar be saturated with vegetable alkali, and add to the solution of the tartrite of pot-ash, thus formed, five parts of sulphat of soda. It will be found, that after evaporation, some sulphat of pot-ash first crystallizes, and afterwards feignette-salt (§ 665).

§ 680.

The *nitric*, *muriatic*, and *fluoric acids* precede the tartareous in their affinities with alkalis and earths: the calcareous earth excepted, whose attraction for the tartareous is greater than for the other acids just mentioned. The *boracic acid* has a weaker affinity with all alkalis and earths, than the tartareous.

Of the soluble cream of tartar (Cremor tartari solubilis).

§ 681.

The great tendency of tartareous acid to unite with a certain definite portion of vegetable alkali,
and

and to form by this combination tartar of so difficult solubility (§ 658), produces a seeming exception from the general laws of affinities. Even such acids, the acetic for instance, as are not so strongly attracted by pot-ash as the tartareous, decompose the neutral tartrite of pot-ash, and separate from it—not the tartareous acid, but tartar.—And thus also, whenever tartareous acid is added to the solution of any neutral salt, whose basis is *pot-ash*, as muriat of pot-ash (§ 539), tartar is again generated.

Salt of Wood-Sorrel.—Oxalic Acid.

§ 682.

If the fresh leaves of *wood-sorrel* (*oxalis acetosella*, *oxal. corniculata*) or of *garden-sorrel* (*rumex acetosa*) be bruised or pounded in a wooden mortar; if their juice be then expressed, and after purification by rest and filtration, it be further clarified by boiling with the white of eggs; and lastly, evaporated, and left in glass bowls for spontaneous imperceptible exhalation, the essential salt of these plants will shoot into crystals round the sides of the vessel. This is what is called *salt of wood-sorrel* (*sal acetosellæ*). Its crystals require a repeated solution in water, filtration, evaporation, and crystallization, to render them white and pure. This salt is chiefly and in

large quantities prepared in the *Schwarzwald* (Black-Forest in Germany).

It is obvious that this salt cannot be prepared with any prospect of profit, unless in such territories where there is an abundance of the plant, and at the same time plenty and cheapness of fuel: when it is considered, that according to *Hermstädt*, from 50 pounds of the fresh plant, 25 pounds of juice, and from these hardly more than 2 ounces of salt are obtained.—Edit.

§ 683.

The crystals of the salt of forrel are minute, of an undetermined figure, permanent in the air, and with difficulty dissolved by cold water. Of boiling water they require 6 parts for solution. The acid contained in this salt is much stronger than that which is obtained from tartar. It is not volatilized by the heat of boiling water.

§ 684.

Salt of forrel is as little a pure vegetable acid as tartar. It is, on the contrary, the vegetable alkali over-charged with a peculiar acid belonging to this salt. Exposed to fire, it melts after some decrepitation; gives out a very pungent four vapour, and leaves pot-ash behind. When subjected to dry distillation, it emits carbonated hydrogen and carbonic acid gas; and besides, an acid fluid, together with some sublimed concrete acid. But it yields no empyreumatic oil, nor is there any

any coaly residuum left, but mere vegetable alkali.

§ 685.

Consequently, the acid of the salt of sorrel is decomposed in heat, like the tartareous (§ 684). And for this reason, the dry distillation of this salt is not a suitable expedient for producing its acid in the same state in which it existed in the salt. This purpose can only be accomplished by separating the acid in the humid way, and in the following manner:

The salt of sorrel is first saturated with ammoniac, whereby a triple salt is obtained; consisting of the acid peculiar to that salt, of pot-ash, and of ammoniac. To the solution of this triple salt a solution of barytes in nitric acid is gradually added by drops, and as long as any precipitate takes place. By so doing, the acid of the salt of sorrel combines with the barytes into a middle salt of very difficult solution, which precipitates; while on the other side, the nitric acid, pot-ash, and ammoniac unite, and form together a new, and very soluble triple salt. The oxalat of barytes, which is the above precipitate, isedulcorated with cold distilled water; put into a matraass, and again decomposed by affusing upon it diluted sulphuric acid; which, from its stronger affinity, seizes the barytes, forming with it sulphat of barytes (§ 423), and sets free the acid of the salt of sorrel.—This
acid

acid mixes now with the diluting water, by which it is held in solution.

Nothing then remains, but to filter the solution, and to suffer it gently to evaporate; upon which the acid crystallizes. The sulphat of barytes remaining on the filter ought also to be edulcorated.

§ 686.

This acid, thus obtained, is called *oxalic acid*, and we cannot help considering it as a distinct peculiar acid of the vegetable kingdom. Its crystals have at times the form of rhomboidal tables with truncated lateral edges; but are usually spear-shaped. The taste of this acid is extremely sour. The oxalic acid itself is much more soluble in water than the salt of sorrel; and it is not volatile in the heat of boiling water.

The oxalic acid goes also by the name of *acid of sugar*.

Indeed it may be obtained from that substance in a cheaper, and speedier way; as will be shewn § 728.

—Edit.

§ 687.

The basis of oxalic acid is a compound. If that acid be distilled by itself, we obtain from it carbonated hydrogen gas, carbonic acid gas, a little sour phlegm, and some sublimed concrete acid salt, which still retains the properties of oxalic acid. Nothing remains in the retort, but a small quantity

quantity of a grey or brown residue, which almost totally disappears in open fire. The salt, that was sublimed, is farther destroyed by distilling it a second time.

§ 688.

Hence it follows, that the radical of oxalic acid is, like that of the tartareous, composed of hydrogen and carbon.—The oxalic is distinguished from the tartareous acid by nothing else than by a different proportion of oxygen, and of the principles of its basis. The tartareous acid may, for this reason, be transformed into oxalic, by distilling weakened nitric acid upon the former in a low heat; by which management nitrous and carbonic acid gases are generated. By concentrated nitric acid, and stronger heat, the tartareous is converted into acetic acid (§ 674); and the same happens to the oxalic, when treated in the same manner.—Thus also the concentrated sulphuric acid is decomposed in heat by the oxalic; and acetic, sulphureous and carbonic acids, are produced, and volatilized.

§ 689.

If into oxalic acid, dissolved in water, a solution of pot-ash be dropped, and the quantity of water be not too great, a four saline powder will immediately precipitate, whose properties are in every respect like those of the salt of sorrel.

1. If the pot-ash be fully saturated with oxalic acid, the product of this combination is the *oxalat of pot-ash*: a neutral salt by far more soluble, than salt of sorrel. However, neither this, nor 2. the *oxalat of soda*, nor 3. the *oxalat of ammoniac*, are in any way employed in arts or medicine. They are all of them destroyed by fire,

§ 690.

4. Calcareous earth has a very powerful attraction for oxalic acid, and constitutes with it a mixture insoluble in water. If a little of a solution of oxalic acid be dropped into lime-water, the acid and the earth will instantaneously combine, and as readily precipitate: forming a middle salt, the *oxalat of lime*. This salt is destitute of taste; it is destroyed by fire, without leaving a coaly residue; and is by this property distinguished from tartrate of lime.

§ 691.

5. Another earthy saline combination of this acid, 6. the *oxalat of magnesia* is likewise insoluble in water. 7. The *oxalat of barytes* is of very sparing solubility; 8. the *oxalat of alumine*, or argil, on the contrary, is deliquescent.

§ 692.

The successive order of affinities of the oxalic acid with alkalis and earths, is as follows.—Lime,
barytes,

barytes, magnesia, pot-ash, soda, ammoniac, alumine.

§ 693.

As to affinities with alkalis and earths, comparatively with other acids, the oxalic acid by far exceeds the *carbonic*. It is inferior to the *fulphuric*, with regard to barytes and alumine; but superior to it with lime and magnesia. Both the *nitric* and *muriatic acids* exceed the oxalic in their affinities with alkalis and alumine; but are inferior to it with lime, magnesia, and barytes.—By the *fluoric acid* the neutral oxalats (§ 689) are decomposed; but not the oxalats of the middle, or earthy saline kind (§ 690, 91). And the *boracic acid*, through the whole list of alkalis and earths, has a more remote affinity than the oxalic.

§ 694.

From the very strong attraction which the *oxalic acid* has for lime, even superior to that of the *fulphuric* (§ 693), it proves an *excellent reagent* for discovering calcareous earth in any fluid; even when this earth is united to an acid. Thus, for instance, the addition of oxalic acid to common water, impregnated with gypsum, or sulphat of lime, immediately destroys its limpidity, and oxalat of lime is precipitated. This purpose is best answered by the oxalat of ammoniac.

§ 695.

§ 695.

Like the tartareous acid, the oxalic has a strong tendency to combine with a certain quantity of pot-ash; thus forming common salt of sorrel. This phenomenon is in appearance another anomaly, or deviation from the laws of attraction, exerted by pot-ash on acids.

Citric Acid.

§ 696.

The juice of lemons, or limes (*succus citri*), contains also a peculiar acid of its own; but united with foreign, especially mucilaginous parts, from which it must be separated in order to produce pure *citric acid*.

§ 697.

For this purpose, the juice of lemons, procured by pressure, is heated; then refined by straining and filtering, and saturated with powdered chalk, until all effervescence ceases.—The precipitate formed is calcareous earth, saturated with acid of lemon, or *citrat of lime*: of difficult solubility, and separable from the fluid by subsequent filtration. It ought also to be edulcorated with cold water. As the sulphuric acid has a stronger attraction for lime than the citric, this last is disengaged from the citrat, by means of diluted sulphuric acid, affused upon it

it in a sufficient quantity*, and with which, after proper stirring, it is boiled for a few minutes. After refrigeration, the contents of the matrafs are filtered; the remainder on the filter being gypsum, and the filtered lye being pure citric acid, which by evaporation of the diluting water is rendered capable of crystallizing; at the same time, that the gypsum, formed by the union of sulphuric acid with lime, and of which still a part remains dissolved in the liquid, is separated, and subsides.

* The requisite quantity of sulphuric acid is that which is required to saturate the lime. Hence the portions of chalk added to the juice of lemons must be noted down, and the quantity of sulphuric acid required for its saturation regulated accordingly. This proportion, if not known by other facts, or by the tables that have been given of such processes, may be found out by a separate trial in small quantities. For instance, half an ounce of chalk may be saturated, adding the sulphuric acid by small portions, and taking notice what quantity of it is required to effect the saturation. The same method holds good as a general rule in all other such operations.—Edit.

§ 698.

The crystals of citric acid have an octahedral shape, truncated on their solid angles or points. They are permanent in the air; are with ease dissolved by water, and excite a very sour taste.

§ 699.

Citric acid is, like all the other acids peculiar to vegetables, destructible by fire; and it yields by dry distillation, carbonated hydrogen gas, carbonic acid gas, an empyreumatic four phlegm, and leaves some coal behind.

§ 700.

By this fact it appears, that hydrogen and carbon likewise constitute the radical of citric acid; but, doubtless, in proportions of these component parts to oxygen, different from those by which the tartareous and oxalic acids are formed. On a similar treatment with these last (§ 673, 688), the citric acid likewise in heat robs the sulphuric acid of part of its oxygen, is itself converted partly into acetic, and partly into carbonic acid; and the sulphuric acid assumes the state of the sulphureous.

§ 701.

The citric is distinguished from other vegetable acids by particular neutral and middle salts, denominated *citrats*, which it forms with alkalis and earths. 1. The *citrat of pot-ash*, and 2. the *citrat of soda*, are crystallizable; but, 3. the *citrat of ammoniac* is not so. Of the middle salts of this kind, 4. the *citrat of lime* * is earthy and tasteless; 5. the *citrat of magnesia* deliquescent; 6. the

6. the *citrat of barytes*, and lastly, 7. the *citrat of alumine*, both of difficult solution.

* Synonyma : *Oculi cancrorum citrati, conchae citratae.*

§ 702.

We have seen that the citric acid is decomposable or destructible by fire (§ 699), and for this reason, all citrats, whether earthy or alkaline, are destroyed by heat; yet it seems to be worth while to investigate farther the nature and properties of these salts.

§ 703.

The following is the order in which alkalis and earths succeed each other, with regard to the degree of affinity with citric acid.—Ponderous earth, lime, magnesia, pot-ash, soda, ammoniac.

§ 704.

In the humid way, both the carbonic and boracic acids are expelled from alkalis by the citric; which, however, has a weaker affinity for the alkalis, than all the other acids hitherto treated of. The *citric acid* is, besides, distinguished from the two preceding vegetable acids: first, from the *tartareous*, by not decomposing, like this (§ 681), the muriat of pot-ash; and, secondly, from the *oxalic acid*, by its not decomposing gypsum, which is decomposed by this last (§ 693).

Malic Acid.

§ 705.

Verjuice or the juice of all sorts of unripe or sour apples contains an acid of a peculiar kind, which has been denominated *malic acid*.

After the unfermented juice pressed out from apples has been clarified, it is saturated with chalk; this solution is in the next place strained and mixed with alkohol, or rectified ardent spirit. The alkohol unites with the watery parts of the juice; and the acid uniting with the calcareous earth, forms *malat* of lime, which precipitates, and is separated from the supernatant liquid, by means of a filter. Lastly, the malic acid is disengaged from the washed *malat* by diluted sulphuric acid; which, by virtue of its stronger attraction, lays hold of the lime, forming with it gypsum, and thus sets the malic acid at liberty.

§ 706.

The malic acid never crystallizes, but continues liquid. Of its neutral combinations, 1. the *malat* of *pot-ash*, 2. the *malat* of *soda*, and, 3. the *malat* of *ammoniac* are all deliquescent. Of its combinations with earths, 4. the *malat* of *lime* admits of being crystallized, and also, 5. the

the *malat* of barytes; 6. the *malat* of *magnesia* is again deliquescent; but, on the contrary, 7. *malat* of *alumine* is of difficult solution.

§ 707.

Fire decomposes the malic acid, and likewise all its neutral and middle-salts. By distilling dry *malat* of lime, carbonated hydrogen gas, and carbonic acid gas are produced, as from the foregoing vegetable acids; and the calcareous earth, together with a coaly residue, remains in the retort. It follows from this, that the radical of malic acid likewise consists of hydrogen and carbon. By a small portion of the nitric acid, the malic acid may be converted into the oxalic.

Concerning other four Juices of Plants.

§ 708.

The acids afforded by other plants have been found not to differ from those which we have before examined.

Thus from *tamarinds* (*tamarindus indica*) tartareous acid, and tartar, are also obtained; and citric acid, according to *Vauquelin*.

The juice of *sour cherries* (*cerasum apronianum*) contains citric and malic acid.

The berries of *sumac* (*rhus coriaria*) contain tartareous acid and tartar.

Common cranberries (*vaccinium oxycoccos*), red bilberries (*vaccinium vitis idæa*), the bird cherry (*prunus padus*), the berries of bitter-sweet (*solanum dulcamara*), and hips (*cynosbatus*) contain more citric than malic acid.

Berberries (*berberis vulgaris*), elder-berries (*sambucus nigra*), sloes (*prunus spinosa*), berries of the wild service-tree (*sorbus aucuparia*) and the common plum (*prunus domestica*), contain more malic than citric acid.

Gooseberries (*ribes grossularia*), white and red currants (*ribes album et rubrum*), whortle-berries (*vaccinium myrtillus*), strawberries (*fragaria vesca*), and raspberries (*rubus idæus*), contain almost equal portions of citric and malic acid.

Unripe grapes (*uva immatura*) contain merely citric acid.

Benzoic Acid.

§ 709.

In the fragrant resin called *Benzoin* there exists a salt, which on account of its properties cannot but be considered as a distinct vegetable acid, known by the appellation of *Benzoic Acid*.—The method of pro-

procuring it is this.—Benzoin is exposed in a crucible to a gentle heat; a cornet of paper, conically twisted, with the open base turned downwards, is placed on the aperture of the crucible. A strong, white, very pungent smoke sublimes from the resin, settling around the inside of the paper in white glittering needles, whose officinal name is *flowers of benzoin*, and which are the benzoic acid.

§ 710.

The benzoic acid may be procured more copiously, and in a less troublesome way, by boiling four parts of finely pulverized benzoin with one part of burnt lime, and four parts of water.

The operation should be performed in a pewter vessel, and with constant stirring. The acid contained in the resin unites with the calcareous-earth to a middle salt, which remains dissolved in the lixivium, and must be filtered. The residuum is again boiled, but with a double quantity of water; and, when boiled, filtered and mixed with the first lye. Both lyes together are now in part evaporated; and, after they have cooled, muriatic acid is dropped in till no more precipitate subsides.

This precipitate, carefully lixiviated with cold water and dried, is the benzoic acid, which is purified by repeated solutions in boiling water and

filtration; and may, by slow refrigeration, be caused to shoot into beautiful crystals in the shape of needles, or short silky threads.

The muriatic acid, by its stronger affinity, seizes the lime, and forms with it a soluble salt. But as the benzoic acid is less soluble, and the quantity of water necessary for its solution is diminished by evaporation, it falls down; and still more so, as the solvent power of water decreases by cooling. The precipitate, in the first part of the operation, is of a powdery form.—
Edit.

§ 711.

The acidity of benzoic acid is not predominant; its taste is, however, of a very irritating and acrid kind. In cold water it is of very difficult solution; boiling water has a much greater power upon it. Its crystals are not affected by the influence of air; but they are volatile in moderate heat (§ 709). They are combustible; but, to be burnt, they must be placed in immediate contact with red-hot charcoal. They also detonate with ignited nitrat of pot-ash.

§ 712.

The basis of this acid appears likewise to be a compound of hydrogen and carbon. Yet these principles must in this acid bear proportions to each other, as well as to oxygen, different from those by which the vegetable acids mentioned before are formed,—This acid salt being volatile in
fire,

fire, its decomposition is not an easy matter. Yet, by being distilled with sulphuric acid and the native black oxyd of manganese, it is decomposed, and becomes acetic acid.—The concentrated sulphuric and nitric acids are not decomposed by it in the humid way; and both dissolve it easily, but drop it again unaltered on the addition of water.

§ 713.

The benzoic acid combines with all alkalis, and with alkaline earths, forming by this union crystallizable, neutral, and middle salts, of which till now no use has been made.

1, *Benzoat of pot-ash*; 2, *benzoat of soda*;
3, *benzoat of ammoniac*; and

The *benzoats*, 4, of *lime*; 5, of *magnesia*; 6, of *alumine*; 7, of *barytes*; 8, of *Strontian-earth*.

§ 714.

The affinities of alkaline substances with the benzoic acid are in this order: First, lime; then barytes, pot-ash, soda, ammoniac, magnesia, and last of all alumine.

§ 715.

By the benzoic acid the *carbonic* and *boracic acids* are expelled from alkalis and earths. The benzoic is, on the other hand, itself expelled from these substances by the sulphuric, nitric, nitrous,

fluoric, tartareous, oxalic, citric, and malic acids. The explanation of these phenomena is, as in all other cases of this kind, to be found in the laws of attractions.

Gallic Acid.

§ 716.

Various plants, entirely or in part, manifest an astringent taste; and are also possessed of the characteristic property, that their aqueous or spirituous infusion precipitates the sulphat of iron (green vitriol) from its solution, of a black or black-blue colour.

§ 717.

These qualities are possessed in an eminent degree by the *nut-galls*; and, besides, by the *bark of oak*, *sumach*, the *rinds of pomegranate*, *tormentil-root*, *bislort* or *snake-weed*, and several others.

§ 718.

From nut-galls subjected to dry distillation carbonated hydrogen gas, and carbonic acid gas, are extricated; besides these, a sour phlegm and empyreumatic oil comes over; and at the same time sublimes a light resplendent salt, evidently sour, which may be purified by subliming it a second time with a gentle heat in two glass-cups fastened to-

together, and may be thus brought to the form of rather long shining crystals, radiating from a common centre, and crossing one another. Part of this salt is also contained in a dissolved state in the above acid fluid, which is collected in the receiver when dry nut-galls are distilled.

§ 719.

Besides this method, the above acid salt may be obtained from nut-galls in various other ways.—It constitutes a peculiar acid belonging to the vegetable kingdom, and is distinguished by the name of *gallic acid* *. Iron is precipitated of a black hue from its saturated solution in acids by this salt, even without any addition. From this, therefore, we must explain that property, which the nut-galls possess in common with other astringent plants. But the extracts of nut-galls, the spirituous as well as the aqueous, contain, besides this gallic acid, some mucilaginous, resinous, extractive matter; which, in the opinion of *Dejeux*, constitutes in these nuts, together with the acid, a compound which, by these ingredients, is rendered soluble in water as well as in spirit of wine.

* It is also called *astringent principle*.

According to *Chaptal*, *Elements de Chymie*, 1795, Tome II. page 331, the solution of gold is by this acid rendered of a dark green, and the metal is reduced and precipitated as a brown powder. The solution
of

of silver is turned brown by it, and the *silver* falls down as a grey powder in the metallic state.—*Mercury* is by this salt precipitated of an orange-yellow, *copper* of a brown, and *sugar of lead* of a white colour.—Edit.

§ 720.

By nitric acid the gallic may be converted into oxalic acid. By this circumstance it seems to me unquestionable, that the gallic acid has also a basis composed of hydrogen and carbon; but which, of course, must be supposed to contain these principles in proportions different from those other vegetable acids, as well relatively to each other as to the share of oxygen. *Dejeux*, nevertheless, asserts, that its radical is simply carbon; and that the difference of gallic from carbonic acid consists merely in the different quantities of their oxygen.

§ 721.

The neutral and middle salts, or *gallats*, formed by the gallic acid in combination with alkaline substances, have not yet been sufficiently examined. All of them have the property of precipitating iron of a black colour.

1. *Gallat of pot-ash*; 2. *of soda*; 3. *of ammoniac*.
4. *Gallat of lime*; 5. *of magnesia*; 6. *of alumine*; 7. *of barytes*; 8. *of Strontian-earth*.

Sugar.

Sugar.

§ 722.

Sugar (saccharum) is a true essential salt of the vegetable kingdom, contained in all plants of a sweet taste, and in their parts; though it can only be extracted from a few in a state of purity and with profit. It is a product of nature, and art can do nothing else than separate and purify it.

§ 723.

Common sugar is prepared, particularly in the *West-Indies*, from the juice of the *sugar-cane (saccharum officinarum)*. This juice being greatly disposed to ferment, it is indispensably necessary to separate the sugar as soon as the juice has been pressed out of the cane. This is effected by evaporation and coagulation; but to succeed in it, the saccharine acid contained in the liquor, and which would prevent the sugar from coagulating, must be first parted by adding lime, and the liquor be well skimmed.—The sugar is made to coagulate by properly inspissating the saccharine liquor and by cooling; after which the mother-water (*mellasses* or *treacle*) is drained off.—Sugar thus procured is called *raw sugar*, or *moscovade*; is of a yellow colour, and is sent.

sent to Europe in this state for farther refining. Sugar farther purified from melasses, is called *powder sugar*, and also *cañonade*.

The last and complete purification, or *refining of sugar*, is done in the following manner:—Raw sugar is boiled again in copper-kettles with lime-water and bullock's blood, carefully despumated and strained through woollen-cloth, and once more boiled down to a proper degree of consistence. This saccharine decoction is now ready for cooling, which is performed by lading it first into a large copper cooler, and by transferring it from this into flat pans well moistened before hand, where it is repeatedly stirred to prevent its coalescing into larger crystals.—When completely cold it is put into unglazed conical moulds made of clay, the lower small aperture of which is stopped up. In these it is suffered fully to coagulate. But the superfluous syrup is caused to trickle off, by opening the lower points of the moulds.

Sugar thus prepared is called *loaf-sugar*. An ingenious way of freeing it from the adhering particles of syrup, and of making it perfectly white, has been contrived, by covering the base of the inverted conical form with clay, previously softened by maceration in water, of the thickness of several inches, and which is now and then moistened with a little water. By this excellent contrivance the
small

small crystals of sugar, though of so deliquescent a nature, are washed and cleansed from adhering foul water; and, besides, the colouring particles and other impurities are dissolved and carried off.—The operations here mentioned are several times repeated until the sugar has obtained the whiteness and fineness required.—At last the sugar-loaves are thoroughly dried in heated rooms.

§ 724.

The *syrup* collected on the inspissation of the juice pressed from the cane, as well as that which is obtained at the refining of sugar, is only produced and generated by the operation. It is sugar which, at a heat exceeding the degree of boiling water, has already suffered a beginning decomposition.

§ 725.

Sugar is neither an acid nor an alkaline salt; it is neither a neutral nor a middle salt; it is in every respect to be considered as a salt of a peculiar nature. Sugar is very soluble in water, and requires at 50° Farenh. no more than 1,333 parts of it.—Sugar may be crystallized, as is obvious from *sugar-candy*, which is prepared by leaving a purified solution of sugar not yet boiled down to a very thick consistence, to quiet exhalation in strongly heated chambers, in copper or brass vessels, containing a number of threads crossing each other, and fastened

to

to the sides in various directions. The sugar thus circumstanced settles and crystallizes round the threads and sides of the vessel.

Accordingly, as the sugar employed for this purpose has been purified in various degrees, the sugar-candy will be *brown, yellow, or white*.—The crystals of sugar form a quadrangular, flattened, oblique column, with terminations truncated on two sides. Each of the smaller lateral surfaces of the column, however, is usually composed of two, joining in a very obtuse angle. The crystals of pure white sugar-candy do not deliquesce in air.

§ 726.

Sugar is a combustible substance, and is destroyed by fire. Exposed to heat it gives out a strong acidulous smoke; it intumesces, and burns to a coal, which being incinerated scarcely leaves a residue behind. A large quantity of carbonic acid gas, and of carbonated hydrogen gas, is obtained from it by distillation; and, besides these, an empyreumatic acid spirit, but only a small portion of empyreumatic oil; and there remains a very spongy coal.—The acid spirit obtained in this process ought to be taken for a mixture of acetic with oxalic acid; and does not deserve to be received in the system as a peculiar acid with the name of *pyromucous acid*.

§ 727.

Hence the component parts of sugar are carbon, hydrogen, and oxygen; but it does not contain a sufficient portion of the last to form an acid with the first. Notwithstanding this, if the proportion of oxygen be indirectly augmented by taking off a part of its carbon, sugar becomes then a true acid, and may be converted into oxalic acid by the nitric; and, by fermentation, into acetic acid.

§ 728.

To effect this pour six parts of nitric acid upon one part of pulverized white sugar. A frothing takes place, and nitrous mixed with carbonic acid gas is discharged. Keep the whole in a gentle warmth until no more yellow-reddish vapours arise, and let the residual lixivium quietly cool.—Crystals of oxalic acid will thoot out. When these have been taken out, the remaining lye may be totally changed into oxalic acid, if a fresh portion of diluted nitric be added, and the fluid be evaporated and cooled, after the effervescence has ceased.

Bergman, and many others, took this for a particular acid, distinguished from others; and it was called *acid of sugar*. But *Scheele*, the discoverer of the method (§ 685) of preparing oxalic acid, has proved, beyond doubt, that the acid obtained from sorrel is identically the same as that obtained from sugar. This was confirmed by the experiments of *Westrumb* and *Hermstaedt*.—Edit.

§ 729.

§ 729.

Sugar is widely diffused in the vegetable kingdom; all sweet-tasted fruits and plants contain it: only, because it is so often united with mucilaginous and extractive matters, it cannot be obtained from them all, especially in a profitable way. The juice that flows in the spring from the *sugar-maple* (*acer saccharinum*), by an incision made in its stem, yields a true sugar, if properly purified and boiled down. It is at present advantageously employed for that purpose in North-America.—Sugar has likewise been obtained from *parsnip-roots* (*pastinaca sativa*); from *skirrets* (*sum sisarum*); from *white and red beet-roots* (*beta cicla*); from *carrots* (*daucus carota*); and from the stalks of *India corn* (*zea mays*)*.

* The latest experiments made with these plants for the purpose of preparing sugar from them are those of *Hermstaedt*. His paper on that head, translated from the *Neue Schriften naturforschender Freunde zu Berlin*, has been given in *Nicholson's Journal*, Vol. III. for the month of October, 1799.—Edit.

The *sugar-maple*, however, seems to answer that purpose with the greatest profit.—As there are not yet sufficient plantations of that tree in Germany, *Klaproth*, *Achard*, and *Hermstaedt*, of Berlin, attempted to prepare it from a beet called *runkelrübe* by the Germans (*beta cicla altissima yaquin*), and succeeded beyond expectation. The sugar which it yields is as good as raw Lisbon sugar, and the pound of it will hardly cost

cost three-pence. In all appearance it promises fair to be, within a few years, a substitute for the West-India sugar. Those chemists are now about discovering a cheap method of refining it. Of the very simple process of preparing that sugar by the mere evaporation of the liquor pressed out from the mashed root, a short account is given in the *Philosophical Journal*, April, 1799, page 291; and *Nicholson* has inserted *Achard's* circumstantial description of the method of cultivating the *runkelrübe* in his *Journal* for September, 1799, page 237, seq.—Editor.

§ 730.

Among the sweet essential salts of the vegetable kingdom manna and honey are also to be reckoned. *Manna* exudes from various species of *ash*, particularly the *fraxinus rotundifolia* and *ornus*, either naturally, or by incisions purposely made on the trunk of the tree.—*Honey* is the work of bees; but its origin, and the materials collected for it by these useful insects, is vegetable. Of these two honey is, perhaps, most profitably employed, as it contains so much sugar that its small crystals are visible, after it has stood for some time.

Mucilage of Plants.

§ 731.

Various parts of vegetables, for example the roots of *marsh-mallows*, the kernels of *quinces*, impart to water, if boiled with them, a certain toughness

and glutinosity, yet without much sensible sapidity. The substance which, in this case, is dissolved by water, is called *slime*, *mucus*, *mucilage*, and remains behind, when the decoction, previously strained; is totally evaporated by a low heat.—The mucilage, when in this state, forms a body devoid of taste and smell, not soluble in ardent spirit, but which is dissolved by cold as well as hot water.

§ 732.

This mucilage exists in all plants and their parts, with this difference only, that it cannot be procured in a pure state from every one of them. It is also found in some plants, and in some of their parts, more plentifully than in others.

§ 733.

Some trees suffer their mucilage to transude either spontaneously, or by incisions made in them. When it has become concrete by drying in the air, it is called *gum*.

Examples are afforded by *gum-arabic* from the *mimosa nilotica* and *mim. senegal*; the *gum* from the *plum*— and *cherry-tree* (*gummi cerasorum*); and *gum tragacanth* from the *astragalus tragacantha*.

§ 734.

Mucilage is susceptible of combustion. It yields, by dry distillation, carbonic acid and carbonated hydrogen

hydrogen gas, an acid empyreumatic fluid like sugar, and an empyreumatic oil. The remaining coal is very pure; and whatever is left behind, after its incineration, proceeds from some adhering extraneous matters.

§ 735.

The mucilage may be changed into oxalic acid by the nitric; and *Vauquelin* has converted it, by muriatic acid, into the citric.

§ 736.

The constituent parts of vegetable mucilage and gum are, therefore, carbon, hydrogen, and some portion of oxygen (§ 734), and consequently the same as those of sugar (§ 727).—There is, therefore, no other difference between them, than a variety in the proportions of their radicals to each other; and hence their transition from one into another is easy while the plant is growing.

Of Refin.

§ 737.

Refin (*refina*) is insoluble in water, but soluble in spirit of wine. It liquefies by heat, may be easily set on fire by applying a flame, and is possessed of an odour more or less strong.

§ 738.

Resin is a proximate constituent ingredient in several parts of vegetables. It is particularly found in the wood, roots, and buds. It may be extracted from them by ardent spirit; but there are some trees that suffer it to exude spontaneously.

To this class of bodies belong *pitch* (§ 632); *colophony*, made by the farther refining of Burgundy pitch; *masfic*, from the *pistacia lentiscus*; *sandarac*, from the *juniperus communis*; *elemi*, from the *amyris elemifera*; *tacamahac*, from the *populus balsamifera*; (?) *benzoin*, from the *styrax benzoin*; *frankincense* (*olibanum*), from the *juniperus lycia*; *guaiacum*, from the *guaiacum officinale*; *dragon's-blood*, from the *calamus rotang*, *dracæna draco*, and *pterocarpus draco*; *copal*, from the *rhus copallinum*; *ladanum*, from the *cistus creticus*, and *shell-lac* (*lacca in tabulis*).

§ 739.

Such resins as spontaneously issue from their plants, owe their fluidity to an ethereal oil combined with them, which itself is a constituent part of vegetables; and the resins harden after its exhalation. It is from this oil that the fragrant smell of resins originates. Resins, which have not yet assumed the concrete form; but still continue in a fluid state, are called *natural balsams**; and they may be considered as resins dissolved by ethereal oils.

Examples:

Examples: *Common turpentine* (*terebinthina vulgaris*), obtained from firs and pines; *Venetian turpentine*, from the *pinus larix*; *Cyprian turpentine*, from the *pistacia terebinthus*; *Canada balsam*, from the *pinus balsamea* and *canadensis*; *Copaiwa balsam*, from the *copaifera officinalis*; *balsam of Peru*, from the *myroxylon peruifera*; *balsam of Tolu*, from the *toluifera balsamum*; *balsam of Mecca*, or *Gilead* (*opobalsamum liquidum*), from the *amyris opobalsamum*.

- * Fluidity and fragrancý seem to be essential requisites to the nature of a balsam. Yet *Chaptal*, with some others, asserts, that several balsams are always in a concrete state; and, according to him, they are resins united to an acid salt. *Elem. de Chymie*, Tome III. sect. 3, article 4.—Edit.

§ 740.

Pure resins, when burned in oxygen gas, generate carbonic acid gas and water. Besides, if distilled by themselves without other addition, except a large quantity of sand (which is necessary on account of their great intumescence), they afford carbonated hydrogen gas, carbonic acid gas, a fourish fluid, and much empyreumatic oil, which at the end becomes quite pitchy. The remaining coal is very pure.

§ 741.

The radicals of resins are consequently carbon, hydrogen, and some oxygen. They may also be produced artificially from ethereal oils, as will be shewn hereafter. Acids affect them but little.

Gum-Resin.

§ 742.

That juice, for the most part milky, which issues from plants wounded by incision, if spontaneously exhaled, or artificially evaporated, leaves a residual substance, which is not completely dissolved either by water or by spirit of wine; and is, from this circumstance, called *gum-resin*. It cannot, with propriety, be considered as a blended mass consisting of resin and gum; it is rather to be taken for a peculiar mixture. Many gum-resins are possessed of a strong smell, and contain various other component parts united with them.

Such gum-resins are: *Gum-ammoniac*; *galbanum*, from the *babon galbanum*; *myrrh*; *euphorbium*, from the *euphorbia officinarum*; *gamboge*, from the *gambogia gutta*; *asa-fætida*, from the *ferula asa-fætida*; *opium*, from the seed-vessels of the *papaver somniferum*.

Naturalists well know the difficulties that occur in arranging the products of nature; hence the reader will not be surprized at finding, in different books, different lists of gums, resins, balsams, and gum-resins. That of our author seems, however, in every respect, to be very rational.—Edit.

Of Gluten.

§ 743.

If wheaten flour be first kneaded with cold water to a firm dough, and if this paste be washed between the hands with cold water constantly flowing upon it, until the water is no longer rendered milky and turbid, but comes off clear and transparent, there will remain in the hands a tenacious *contractile* matter, which, on being forcibly enlarged by pulling while moist, looks glossy, and in some manner like a membrane, and which cannot be dissolved either by water or by spirit of wine.

§ 744.

This peculiar substance has obtained the name of *gluten*. It hardens in heat to a brown horny matter; is dissolved by acids; is consumed by fire, sending forth a smell like that of scorched hairs; and yields, by distillation, carbonic acid— and hydrogen gases, besides some ammoniac, and an empyreumatic oil.—This gluten is tinged by nitric acid of a yellow colour, is decomposed by it, and transformed into oxalic acid.

§ 745.

All experiments made with gluten prove, that it is composed of carbon, hydrogen, azot, phosphorus, and oxygen.

§ 746.

The flour of other species of corn, different from wheat, contains a less quantity of gluten.—This, however, is a constituent principle of many other plants or their parts; of their leaves, for instance, and particularly of the *fungi*. There is no doubt but that the ammoniac, yielded by plants on dry distillation (§ 633), chiefly arises from their gluten.

Concerning Starch,

§ 747.

If the rinsing-water collected from the foregoing experiment (§ 743) be suffered to stand quietly for some time, it lets fall a white powdery sediment. This is the *starch* (*amylum*), which, when dry, is pulverulent, tasteless, without odour, insoluble both in cold water and ardent spirit; but is dissolved by boiling water, making with it *paste*, a well known substance.

This rinsing-water (§ 743) separated from the starch, and filtered, yields, if evaporated before it turns sour, an extract which proves to be of a *mucilaginous saccharine* nature.

§ 748.

§ 748.

On account of these properties we are entitled to say, that starch is essentially different from both mucilage and gluten. By distillation it gives the products yielded by mucilage (§ 734), and consequently consists of the same principles; but in the starch they are united in other proportions than in mucilage.—Nitric acid converts starch into oxalic and malic acid.

§ 749.

Starch is one of the constituent parts in all mealy, farinaceous seeds, fruits, roots, and other parts of plants. Of these the *fecula* of the ancients for medicinal use are an example. They are mere starch; as for instance, the fecula of *wake-robin* (*radix ari, aronis*); of *bryony* (*bryonia alba*); the starch of *potatoes* (*solanum tuberosum*); of *sago*, from the pith of the palm *landanum*; the *cassava* of the Americans, from the *manioc-root* (*jatropha manihot*). The *salep* roots, from a species of *orchis*, consist for the greatest part of starch.

§ 750.

Our common starch is made from wheat. It is not necessary that the grain be first bruised in mills. The entire corn, well cleansed, is soaked in cold water until the husk separates; and the grains, having become quite soft, give out by pressure a milky fluid.

fluid. The grains are then taken out of the water by means of a sieve, put into a coarse linen sack, and transferred into the *treading-tub*; where they are trodden, after cold water has been poured upon them.

By this operation the starchy part is washed out, and mingling with the water makes it milky. The water is now drawn off, running through a sieve into the *settling-tub*. Fresh water is again affused upon the grains, and the same operations continued, till the water in the treading-tub is no longer rendered milky. The starch here precipitates by repose from the water that held it suspended; during which, especially in a warm season, the *mucilaginous saccharine* matter of the flour (§ 747, note), that was dissolved by the water, goes into the ætous fermentation. From this cause the starch grows still purer and whiter.

The water is next let off from the starch, which is several times more washed with clear fresh water; the remaining part of which is suffered to drip through linen cloths supported by hurdles, upon which the wet starch is placed. When the starch has fully subsided, it is wrapt in and wrung between these cloths, or pressed, to extort still more of the remaining liquid. It is afterwards cut into pieces, which are laid in airy places on slightly burnt bricks to be completely dried, partly by the free currency
of

of air, and partly by the bricks imbibing their moisture. Lastly, the outer crust is scraped off, and they are broken into smaller pieces.

In the sacks wherein the corn was trodden there remain its husks and glutinous parts; and this residuum is employed as food for cattle.

Albuminous Matter of Plants.

§ 751.

Take some juice recently pressed from young cresses, or from white cabbage; let it stand quiet for several hours, and then pass it cold through filtering-paper. If a glass bottle filled with this clear and transparent liquor be placed in boiling water, the liquor will deposite a flocculent matter; which being separated by filtering, and washed, resembles the coagulated white of eggs, and for this reason has rightly been called the *albuminous matter* (*albumen*) of the vegetable kingdom.—This albumen, before it coagulates, is soluble in cold water, and of an insipid taste. In heat it coagulates, and this coagulum is insoluble in hot as well as cold water. In spirit of wine it also coagulates, and is likewise insoluble. Alkalis and liquid ammoniac dissolve it.

§ 752.

Fourcroy found, by analysing this substance, every possible agreement, as to nature and properties, between it and the albuminous matter of the animal kingdom; which last will be examined in its proper place.

753.

This albumen has been met with in the juice of a great many plants; and it is this matter, principally, that contributes to the formation of scum, when vegetable juices recently pressed, and clearly strained, are reduced to a smaller bulk by boiling.

Of Fat Oil.

§ 754.

A fluid matter, insoluble in water, and capable of feeding flame if conveyed to it by means of a wick, may be expressed from the seeds and kernels of various plants. This liquid is, therefore, an *oil* (*oleum*). It is, besides, an oil of that kind which is not dissolved by ardent spirit; it soils paper when dropped upon it, leaving a spot which is not made to disappear by warming the paper; and possesses, when fresh and pure, a mild taste, and usually gives no very perceptible smell.---To distinguish it from
other

other oils not having those characters, it is called *fat oil* (*oleum unguinosum*).

Synonyma: *Mild oil, fixed oil, expressed oil* (*oleum dulce, fixum, expressum*).

§ 755.

In order to obtain pure oil of a good quality the seeds and kernels are separated from their hard shells and husks, and all other extraneous matters; they are then bruised, and put into sacks or cloths woven from hemp or horse-hair; and in these they are pressed between metallic plates, first slowly and gently, and afterwards more strongly.—But, to promote the expression of the oil, the bruised seeds are first exposed to the steam of boiling water; or they are placed upon a low fire in a kettle sprinkled with water, and thus carefully warmed, with diligent stirring, to prevent their being scorched, and then pressed between warm metallic plates. By mere cold pressing the oil can by no means be totally got out; yet too great a heat, which would cause a commencement of roasting in the seeds and kernels, is highly detrimental to the oil.

§ 756.

Fat oils are, in the best way (by repose), spontaneously purified from the mucilaginous parts that were pressed out along with them. Resinous and ethereal oily particles which may be contained either
in

in the husk or in the grain of the seeds, impart to some fat oils, by being dissolved in them, colour, taste, and smell.

§ 757.

Several fat oils become dry of themselves in the air, and pass into the concrete state, more especially if they have been boiled beforehand. Others always remain greasy, and some are solid in the common temperature of our atmosphere.—These last are styled *vegetable butters* (*butyra plantarum*).

To drying fat oils belong *linseed-oil*, from the seed of the *linum usitatissimum* and *perenne*; *poppy-oil*, from the seed of the *papaver somniferum*; and *hemp-oil*, from the seed of the *cannabis sativa*.

To the oils always continuing fluid belong *olive-oil* (*oleum olivarum*), from the fruit of the *olea europæa*; *oil of almonds*, from the kernels of the *amygdalus communis*; *rape-oil*, from the seeds of the *brassica napus* and *campestris*; *oil of ricinum*, or *castor-oil*, from the kernels of the *ricinus communis*.

The kernels of *gourds*, *beech-mast*, *walnuts*, *hazel-nuts*; the seeds of *mustard*, of the *sun-flower*; the kernels of *plums*, and of *grapes*, &c. afford also fat oils of economical use.

Among *vegetable butters* are reckoned *butter of cacao*, from the kernels of the *theobroma cacao*; *oil of laurels*, from the kernels of the *laurus nobilis*; and *oil of nutmegs*, from the nuts of that name.

§ 758.

Fat oils do not boil unless in a strong heat, which is estimated at 600° Farenh. They undergo thereby a decomposition. They are inflamed only at a heat sufficient to volatilize them.

§ 759.

Fat oils burn with a flame. If oxygen gas has no sufficient access to this flame, it throws out a foot (*lamp-black*), which is the unconsumed coal of the oil. Hence, in Argand's lamp, the oil continues to burn away without foot or smoke as long as the air can strike, unimpeded, through the axis or cavity of the flame; and aqueous vapours and carbonic acid gas are generated.—According to *Lavoisier's* statement, 321 parts of oxygen gas are extricated from 100 parts of olive-oil on combustion, and 140 parts of water, and 281 of carbonic acid gas are produced. He infers from this, that this fat oil consists very nearly of 79 parts of carbon, and of 21 of hydrogen.

§ 760.

Notwithstanding this, the fat oils contain also some oxygen; for, if they be distilled by themselves, they yield, besides carbonated hydrogen gas and much empyreumatic oil, likewise carbonic acid gas, and a small portion of empyreumatic acidulous phlegm, neither of which can be formed except by a share of oxygen.

Of the oil of bricks (*oleum philosophorum*).

Of Scheele's sweet substance in fat oils.

§ 761.

By age, and careless keeping in warmth, even the very mildest fat oils grow *rancid*, and are tainted with a sharp taste and bad smell. Those are peculiarly liable to this depravation which have been pressed with too great a heat, or have been in some manner roasted. The usual condition of our oil-mills, and of the apparatus made use of for the expression, is the cause that many seeds and kernels, which otherwise would yield an oil of good flavour, afford such as at their very production is rancid, and of a disagreeable smell and taste.

§ 762.

The principle of rancidity in oils lies in the access of oxygen from the atmosphere to their hydrogen and carbon (§ 759); whereby an acid begins to be formed, and the nature and mixture of the oil is altered.

§ 763.

Fat oils and water have no chemical affinity with each other; and oil is never dissolved by water. But an oil may be intimately mingled with it; and then a milky-white, untransparent fluid is formed, which is called an *emulsion*. This vegetable milk, as it were, is prepared by triturating such seeds as contain a fat oil with water, and squeezing the latter again out from the mass.—Agreeably to the different
nature

nature of the seeds, the water may also dissolve various other extractive matters present in them.

§ 764.

Resins and natural balsams are dissolved by fat oils with the assistance of heat. On mucilage, sugar, gluten, albumen, and starch, these oils shew no solvent power.

§ 765.

The fixed alkalis are a very active menstruum for fat oils, and make up with them a new product, called *soap* (*sapo*), and capable of solution in water and spirit of wine. Soap is made by boiling a caustic lixivium of fixed alkali with a fat oil, or tallow, or suet, and stirring continually, till both substances are completely incorporated.—*Soda* yields, with a congealing or drying oil (§ 757), a firm and hard soap. *Pot-ash* affords a soap of much less solidity, and more greasy, unless muriatic acid be added towards the end of the operation; but then the soap is, in fact, produced by the soda.

Of the usual soaps are: *Common soap*, made of tallow; *Venetian* or *Alicant*, or *Spanish soap*, made of olive-oil; *black soap*, made of train-oil; and *green soap*, made of hemp-, linseed-, or rape-oil.

§ 766.

All acids decompose soap, and separate again its oil. If, therefore, into a clear solution of soap in

water, or ardent spirit, an acid be dropped, a turbidness takes place, and the oil is separated. But this last no longer exhibits its former properties: for instance, it dissolves now, totally or in part, in spirit of wine. Whence it follows, that the action of the alkali upon the oil has altered its mixture (§ 759, seq.)

§ 767.

All ammoniacal neutral salts, and likewise the middle earthy and metallic salts, decompose soap.

§ 768.

Various waters obtained from *springs*, or from *wells*, for this reason dissolve soap only imperfectly, or rather they decompose it. Such are called *hard waters*; but, on the contrary, those are called *soft waters* which are free from all earthy middle salts, and dissolve soap completely. On this account *spirit of soap*, or a solution of soap in spirit of wine, is employed as a *re-agent* to discover, whether a water be of the hard or of the soft kind.

§ 769.

Though *liquid ammoniac*, by agitation and trituration, unites with fat oils to a soap, yet this combination is not so perfect as that with fixed alkalis. This *ammoniacal soap* may, nevertheless, by means of double affinity, be procured in greater perfection, if to a solution of a soap made with fixed alkali,

muriat

muriat of ammoniac be added, and the flocculent matter that falls down be separated by filtering.

§ 770.

The preceding soaps are comprized under the name *alkaline*, and are thus distinguished from *earthy soaps*; inasmuch as several earths are capable of a chemical combination with fat oils. Lime-water, for example, decomposes the solution of common soap, and forms a flocculent precipitate; which is a combination of fat oil with lime, and hence a calcareous or *lime-soap*. When dried, this earthy soap is friable; fusible in heat; not soluble in water, but dissolved by spirit of wine if assisted by heat. Acids decompose it.—This calcareous soap is also obtained by combining the solution of common soap with an acid solution of lime.

§ 771.

In a similar way *magnesian*, *argillaceous*, and *barytic-soap*, are prepared according to *Berthollet*; namely, by mixing the solution of common soap with the respective aqueous solutions of the sulphats of magnesia or of alumine, or of muriated barytes.

§ 772.

Sulphuric acid, as before observed (§ 431), is decomposed, and converted into sulphureous acid, by fat oils; because a portion of hydrogen and carbon, which are the radicals of such oils (§ 759),
D d 2
deprive

deprive the acid of part of its oxygen, and take possession of it. The fat oil is by this decomposition likewise changed with regard to its constituent mixture; it becomes a resin, obtains a firm consistence, assumes a dark colour, and is rendered soluble in alcohol.—Such kind of resin has also been denominated an *acid soap*.

§ 773.

With equal facility is the nitric acid decomposed, and transformed into nitrous gas, by fat oils (§ 515). Here again, as in the foregoing case (§ 772), the hydrogen and carbon of the oil rob the acid of a part of its oxygen. The oil is also changed into a true resin. By very concentrated nitric acid the fat oils, especially those of the drying kind (§ 757), may be brought even to spontaneous inflammation, as will be mentioned hereafter, on treating of ethereal oils.

§ 774.

Muriatic acid acts but little on fat oils; but by oxygenated muriatic acid they are thickened.

§ 775.

Sulphur is perfectly dissolved by fat oils with the assistance of heat. This solution of sulphur in oils is called *balsam of sulphur* (*balsamum sulphuris*). It is thus prepared:—A fat oil is heated in a pan, and powdered sulphur is then put into it by degrees,

grees, and with unintermitted stirring. The mixture is very apt to inflame spontaneously. The colour of this sulphureous balsam is brownish or reddish; its odour is disagreeable; its taste rancid and sharp. If the oil has been completely saturated with sulphur while hot, the mixture is afterwards tenacious and firm when cold.

§ 776.

Balsam of sulphur acted upon by heat develops sulphurated hydrogen gas (§ 449) mixed with carbon. That balsam is obviously a combination of three simple inflammable substances, of sulphur, hydrogen, and carbon; which, in this union, attract oxygen more strongly than when singly each by itself. For this reason the oil grows rancid, even whilst the balsam of sulphur is preparing.

Elastic Resin.

§ 777.

The *elastic resin, caoutchouc (resina elastica)*, is a leather-like, contractile, and, in moderate warmth, very distensible matter, which is not dissolved by water, nor by spirit of wine. It issues from a tree of South America (the *caoutchoua elastica*), by incisions made on it; is a viscid, milky-white liquor, which, by absorbing oxygen from the atmosphere, gradually passes into the state of solidity.

Moulds of clay, in the form of balls, are brushed over by layers with this juice till the cover has obtained a certain thickness. In this state it is suffered to dry in solar heat, and smoke; after which the moulds are broken, and their earthy matter shaken out of the resinous bottle thus formed.—This matter seems to exist in various, even indigenous plants.

§ 778.

The elastic resin is softened by heat; it melts at last, swelling up, and spreading an unpleasant odour. On congealing again by cold it remains sticky or adhesive, and never recovers its former elasticity. It may be set on fire, and burns with flame.

§ 779.

When distilled, this resin yields carbonic acid gas, hydrogen gas, an empyreumatic oil, and ammoniac. There remains but a trifling quantity of coaly matter, which affords no alkali by being burnt to ashes.—Hence the radicals of this substance are carbon, hydrogen, azot, and oxygen.

§ 780.

By fat oils the elastic resin is dissolved in heat; and in this state wax also combines with it. According to *Berniard* and *Achard*, the caustic alkalis have no solvent power on it in the humid way.

§ 781.

To give the elastic resin any shape desired, its solution in vitriolic ether has been found very convenient; as, after the evaporation of that fluid, the resin is left with all its original elasticity.—For the same purpose the rectified petroleum has also been employed by *Fabroni*, as equally effectual, and much cheaper.—Another still more convenient method, without dissolving the resin, has been recommended by *Grossart* *.

- * A bottle of this resin is cut in narrow slips, which are softened in ether or in warm water; they are wrapt round the mould, pressing the edges together, and securing them with ribbons and pack-thread twisted round. When dry, the mould is taken out, which is facilitated by softening in warm water. *Annal. de Chym.* Tome XI. page 143, seq.—Edit.

Ethereal Oil.

§ 782.

If from a vegetable body that possesses a strong smell, not easily passing away by rubbing the plant between the finger, a sufficient quantity of water be distilled, the water is impregnated with that odour, and the vegetable matter loses it. Such water is called *distilled water* (*aqua abstractitia, destillata*).

§ 783.

Besides, if for this operation a sufficient quantity of the vegetable substance is employed, together with the distilled water, there will rise an oil essentially different from fat oils.—The difference of this oil from any fat one is evident from its volatility, shewn by its coming over into the receiver; from its leaving no trace or greasy spot on paper upon which it is dropped, and afterwards warmed; from its penetrating smell, agreeing in every respect with that of the plant from which it has been abstracted by distillation; and lastly, from its being soluble in spirit of wine.—This kind of oil is called *ethereal oil* (*oleum æthereum*).

Synonyma: *Volatile oil* (*oleum volatile*); *scented oil* (*oleum odorum*); *distilled oil* (*oleum destillatum*); *essential oil* (*oleum essentielle*).

§ 784.

Ethereal oils are obtained sometimes from all the parts, sometimes only from some particular parts of the plant; as the roots, bark, leaves, flowers, petals, flower-buds, peels of fruits, seeds, the native balsams and gum-resins; and they are in these various parts sometimes of a different nature in one and the same plant. The quantity of ethereal oil obtained from different plants, or their parts, is variable, and always small in regard to the vegetable
matter

matter employed. This accounts for the high price of several of these oils.

In *Wiegleb's Chemistry*, translated by Hopson, or in the *New Edinburgh Dispensary*, 1797, the reader will find tables stating the quantity of ethereal oils, obtained by different chemists from a determinate quantity of certain plants.—Edit.

§ 785.

The smell of ethereal oils is penetrating and strong. Yet it is not every highly odorous plant that affords much oil; even from some, as lilies, May-flower, and violets, no ethereal oil can be obtained, notwithstanding that they give a perfumed distilled water. The taste of ethereal oils is commonly sharp and irritating.

§ 786.

Most ethereal oils are specifically lighter than water, and float upon it. But some are heavier, and sink to the bottom; such as several procured from aromatic plants of hot regions: for instance, the oil of cloves, of cinnamon, of saffrafs-root.—Again, some ethereal oils are very thin and fluid, and do not assume the solid form at the freezing-point of water; others thicken much sooner, of which the oil of fennel and anise-seed are an example; and others, as the oil of roses, have, even at the common temperature, the consistence of tallow.

§ 787.

§ 787.

The colour of ethereal oils is various. Some are *colourless*, as those of turpentine, fennel, anise, and rosemary; some are *yellowish*, as the oils of caraway-seed, of cloves, of cinnamon, of lavender; some are of a *brownish* hue, as those of wormwood, origanum, and thyme; some few are *greenish*, as cajeput oil, and that of milfoil; or *blue*, as that of camomile.

§ 788.

Water actually dissolves a part of the ethereal oil on being distilled from the plant, and receives thereby both taste and smell. Only that portion of oil which the water is not able to dissolve separates by itself. Therefore, if every other circumstance be alike, less oil is obtained in proportion as water is more copiously employed in the distillation. The solubility of ethereal oils in water seems, however, to admit of various degrees; and several fragrant plants yield no separate oil, because it is all dissolved by the distilling-water.

§ 789.

The distillation of ethereal oils, and distilled waters, in great quantities, is performed in the common still (§ 116).

Freshly-gathered tender plants, herbs, and flowers, of a loose texture, are used entire. Hard and solid
bodies,

bodies, as wood, roots, bark or rinds, are prepared by a proper concision. Previous soaking in water, or maceration is necessary, only when by it such parts can be made to sink, as otherwise, by their levity, would swim on the top, and are apt to swell and rise into the head of the still.

The quantity of additional water cannot be well fixed by a general rule; it must, for every particular case, be found out by experience. In the distillation care is taken that the fluid do not pass overwarm, or too hot, lest the oil evaporate. The water in the refrigeratory is kept less cold only when those oils are distilled, which easily grow stiff or coagulate in the cold. The operation is discontinued when the water coming over is no longer milky, or when it no longer exhibits the taste and smell of the body subjected to distillation.

The water distilled, together with the oil, is poured into narrow-necked bottles, which are well stopped, and where it is left standing to give the oil time for separating; and this separation of the oily particles adhering to the sides of the vessel is promoted by gentle agitation. Lastly, the oil is taken off by a syringe; or, by means of a cotton wick, it is drawn over into the bottle appointed for preserving it. By dipping the shorter end into the oil, and inserting the longer one into the bottle,
this

this wick acts as a syphon. Oils that sink in water are parted by a separatory funnel (§ 135).

Some ethereal oils, as the *oleum bergamotte*, and *oleum de cedro*, are obtained by expression; the first from the fresh peels of *oranges*, the second from *lemons*.—In Italy, and such countries where these fruits abound, and where those oils are procured in this way, they are in general better.

Another method of parting the oil from the water is by the separatory glass (*recipient Italien*) (§ 135).—
Editor.

§ 790.

Waters recently distilled are usually infected with a burnt and herbaceous smell and flavour, but become more pleasant by time only, if kept in a cool place. To procure them in the most perfect state, the vegetable matters should not be brought into immediate contact with water, but they should be inclosed in a linen bag hung up in the still, in such a manner that they are penetrated merely by the vapours of the boiling water.—By this method the distilled waters are not in the least exposed to become empyreumatic.

§ 791.

The component parts of the ethereal, like those of fat oils (§ 759), are carbon, hydrogen, and probably somewhat of oxygen. But, of course, these radicals do not bear in the ethereal oils the same proportion to each other, by which they are united

in fat oils.—On combustion in oxygen gas they give more water than the last; and they are also easier inflamed. The coal, which is left behind in only a very small quantity, is the foot of their flame, and is a very pure coal, without any trace of fixed alkali.

§ 792.

The nitric, the fulphuric, and oxygenated muriatic acids, are with great rapidity deprived of part of their oxygen by the ethereal oils; and these oils themselves are thereby converted into resins.

§ 793.

If, to half an ounce of oil of turpentine contained in a crucible, two drachms of strong fulphuric acid be mixed, the mixture quickly stirred with a glass-rod, and then some concentrated nitric acid be immediately affused, a spontaneous, very lively, and sudden inflammation takes place; and that part of the oil which has grown resinous, burns with a blazing flame.—The experiment succeeds also with empyreumatic and drying fat oils (§ 773).

Consult § 174, note 9.

§ 794.

Ethereal oils likewise take up oxygen from the atmosphere; and for this reason they will be depraved, if not preserved in well-closed vessels.—They lose, in time, by that absorption, their peculiar

liar odour more and more; they become tenacious and thick; and are finally transformed into a true, firm resin; and it is at last impossible to distinguish ethereal oils from one another, after they have been spoiled by age.

§ 795.

From this it has been erroneously concluded, that the ethereal oils consist of two proximate constituent parts; of a peculiar, volatile, subtile matter, which has been called *spiritus rector*, *principle of odour*; *aroma*; and of another grosser, resinous part, serving as a receptacle to the former.—It was also inferred, that upon the first of these two the odour of plants and ethereal oils depends; that the odorous principle is by itself soluble in water; that the depravation of any ethereal oil consists in the loss of that principle; and that many fragrant plants cannot yield an ethereal oil in the separate state, but only an odorous water, because they do not contain this resinous part, which is the abode, as it were, of the *spiritus rector*.

But whatever may be imputed to this odorous principle is rather the exclusive property of the ethereal oil itself, considered as such; and the resin, into which such oils are changed on their spoiling, is a product (§ 794), and did in no manner exist in them before.—The generation of this resin rests on a principle similar to that of the rancescence of

fat oils; namely, the alteration in their mixture by the accession of oxygen; which is also placed beyond doubt, by the passing of ethereal oils into the resinous state, caused by nitric acid (§ 792).

§ 796.

The ethereal oils dissolve fat oils, resins, natural balsams, and elastic resin.—All the resins, however, are not with equal ease dissolved by these oils. *Copal*, for instance, is best dissolved by *oil of rosemary*.

Lac-varnishes with ethereal oils.

Falsification of ethereal by fat oils.

§ 797.

With fixed alkalis the ethereal oils combine into a soap, but with much greater difficulty than fat oils. To these *ethereal oily soaps* (*savonules*, by the French) belongs *Starkey's soap*, made of potash and oil of turpentine.—The best way of preparing it is by digesting in a matrafs (§ 78) *one* part of caustic vegetable alkali, with *four* parts of oil of turpentine; and then distilling the oil from it with a low heat, and cohobating it (§ 115) as often as may be necessary, till the salt has completely acquired the saponaceous nature.

§ 798.

Liquid ammoniac dissolves, in distillation, the ethereal oils, though but sparingly.

§ 799.

§ 799.

Sulphur may be dissolved by ethereal oils with the assistance of heat. The product of this combination is a kind of *sulphureous balsam* (§ 775), of a strong offensive smell and taste.—Great precaution is necessary during the digestion, on account of the inflammable vapour thence arising. From its solution, saturated in heat, a part of sulphur separates after cooling in transparent crystals (*sulphureous ruby*).

Of Camphor.

§ 800.

Camphor (*camphora*) is a concrete, solid, white, transparent substance, possessing a strong, penetrating smell and taste, and so volatile as to exhale entirely even in moderate or summer heat. It may easily be ignited, and burns with a flame; but deposits, on combustion, a vast quantity of soot, yet without leaving any residue. It melts in heat, but hardens again by cooling. Water has no solvent power on camphor, though it receives from it its strong smell. Spirit of wine, on the contrary, dissolves it. The specific gravity of camphor is 0,996.

§ 801.

Camphor, as usually sold, is brought to us from Japan, obtained from a tree (*laurus camphora*) growing there; from the roots, leaves, bark, wood, and branches of which it is extracted by distillation, on boiling these parts with water in a kind of still. Camphor thus obtained (*raw camphor*) is impure; and is farther refined in Europe, particularly in Holland, by sublimation, in which it receives the shape of convex cakes.—This purification might also be done by solution in spirit of wine, its subsequent precipitation by water, and by fusion in glass vessels.

§ 802.

Many other plants contain true camphor; and it abounds more than was formerly believed in the vegetable kingdom. Such is the *camphor of Sumatra* (*baros*) from the *laurus Sumatrensis*; the camphor of the roots of galangal (*marantha galanga*), zedoary (*amomum zedoaria*), ginger (*amomum zingiber*); of the seeds of cardamom (*amomum cardamomum*), and cubebs (*piper cubeba*, or *caudatum*).—Besides, many European vegetables contain real camphor in their ethereal or volatile oils, as *thyme* (*thymus vulgaris*); the roots of sweet-flag (*acorus calamus*), of meadow-anemone (*anemone pulsatilla*, or *pratensis*), of sage (*salvia officinalis*), of hyssop (*hyssopus officin.*), of mother of thyme (*thymus serpyllum*), of peppermint (*mentha piperitia*),

peritia), of *rosmary* (*rosmarinus officin*), and others.—*Proust* has extracted it plentifully, by insensible exhalation, from the oils of *lavender*, *rosemary*, *origanum* or pot-marjoram, and *sage*, at Murcia in Spain.

§ 803.

In all probability camphor consists merely of carbon and hydrogen. But experiments are yet wanting, with respect to its combustion in vital air, to ascertain with accuracy the quantities of these radicals, as contained in this inflammable substance.

§ 804.

Camphor is copiously dissolved in the cold by concentrated sulphuric acid, without effecting a perceivable decomposition of that acid; only, when heated, sulphureous gas is raised, together with the vapours of camphor. Water separates again the camphor unaltered from the solution.—If the oxyd of manganese be added to the mixture, the camphor is converted into the acetic acid, and the sulphuric acid is changed to the sulphureous, as was observed by *Doerffurt*.

§ 805.

Concentrated nitric acid dissolves the camphor plentifully and with ease, and quietly without production of heat, and without being decomposed. By repose a fluid separates on the upper part of the clear and limpid solution, which has the colour and
consistence

consistence of oil of almonds, and is called *oil of camphor* (*oleum camphoræ acidum*). This fluid is soluble in alkohol; but by adding water it grows turbid, and the camphor is precipitated.

§ 806.

Kofegarten has succeeded in decomposing camphor, by repeatedly distilling perfect nitric acid from this substance.—He has by this proceeding extracted from it an acidulous salt, which after him was received into the system as a peculiar acid of the vegetable kingdom, styled *camphoric-acid*.—However, *Doerffurd* has proved that this pretended camphoric acid is perfectly the same with the benzoic.—Nor is this acid an educt obtained or separated from the camphor by the process, but a product at that time generated.

§ 807.

Camphor is dissolvable by fixed or fat oils, as well as by the volatile or ethereal. It also combines with resins and balsams, making them adhesive and glutinous.

§ 808.

Alkalis do not unite with camphor; they have no affinity with it; and at present no genuine *camphoraceous soap*, procured by direct immediate combination, is known.

§ 809.

By fusion in gentle heat camphor unites with sulphur, and produces with it a substance brittle and friable in the cold, but tough and tenacious in warmth. Camphor is likewise dissolved in the humid way, by alkaline sulphuret (§ 442), if assisted by heat.

Acrid Vegetable Matter.

§ 810.

Several vegetables, or their parts, which are otherwise inodorous, or emit but a weak smell, excite a local inflammation, if applied for a while, in their fresh state, to the skin; but lose this faculty by drying. When recently gathered, and inwardly taken, they produce poisonous effects. Of this kind are the fresh roots of *squills* (*scilla maritima*); the leaves of *fox-glove* (*digitalis purpurea*); of *wild anemone* (*anemone nemorosa*); of *virgin's bower* (*clematis erecta*); of *wolfsbane*, or *monk's hood* (*aconitum cammarum*); the roots of *blue orris* (*iris germanica*); of *asphodel*, or *king's spear* (*asphodelus ramosus*); of *meadow saffron* (*colchicum autumnale*); of *white bryony*, or *wild vine* (*bryonia alba*); of *wake robin* (*arum maculatum*); and the fruits of *wild cucumber* (*momordica elaterium*).

§ 811.

§ 811.

Since these plants, by having been, during a sufficient time, well dried, lose their sharpness or acrimony, and the effects on the living body thereon depending, it appears that the substance, which gives rise to the violent irritation caused by them, is of a volatile nature; as is confirmed by its being communicated to water and spirit of wine, abstracted from them by distillation. As, therefore, those plants contain no essential oil, no camphor, and in general none of the volatile principles that have hitherto been the object of our enquiries, we cannot with propriety hesitate, to acknowledge this volatile matter to be a particular proximate constituent part belonging to the vegetable kingdom, and to distinguish it from other principles of that kind by the name, *acrid matter of plants* (*materia acris plantarum*).—Its action is not destroyed by acids nor by alkalis, and is not ammoniac, in any form.

§ 812.

In plants which are called *antiscorbutic*, for instance, in scurvy-grass, water-creffes, garlic, onions, horse-radish, common radish, and the seeds of mustard, this acrid principle is combined with oleaginous particles of the ethereal kind, and its effects, it seems, are weakened by this union.

§ 813.

From plants furnished with this matter, we must discriminate those which, outwardly applied on the living body, cause, in fact, a local inflammation, but are not deprived, by exsiccation, of this power, which rather originates from their resinous parts.—Such are, *euphorbium*, or *wart-wort* (*euphorbia helioscopia*); various parts of several species of the *daphne*, of the *guinea-pepper* (*capsicum annuum*), of the *pellitory of Spain* (*anthemis pyrethrum*), &c.

Narcotic Matter of Plants.

§ 814.

The *narcotic*, *soporific*, or *stupefying matter of plants*, is, by its action on the living body, essentially different from their acrid principle; and the venomous properties of several plants which depend on it, manifest themselves in quite a different way. Examples of such plants are, *opium* (*papaver somniferum*); the leaves of the *cherry-laurel* (*prunus lauro-cerasus*); of the *deadly night-shade* (*atropa belladonna*); of the *thorn-apple* (*datura stramonium*); of the *common black henbane* (*hyoscyamus niger*); of the *wild rosemary*, or *marsh andromeda* (*ledum palustre*), &c.

§ 815.

The narcotic principle of plants is volatile, and is dissipated by the decoction of vegetables that possess it. In some of them it is united with an ethereal oil.—In other respects we are as yet very little acquainted with its nature, and the mixture of its radicals.

Fibrous Part of Vegetables.

§ 816.

After all the immediate component parts of plants, related under the preceding heads, are separated, there still remains a residuum, which represents in a certain way the skeleton of the plant, and is distinguished from the others by the name of *fibrous* or *ligneous part* (*materia fibrosa plantarum*). This matter has hitherto been too much neglected, but deserves to be studied more attentively, as one of the proximate constituent parts of the vegetable kingdom.

The fibrous vegetable matter is insoluble in water, in spirit of wine, in oils and alkalis; but it is destructible by concentrated sulphuric, nitric, and oxygenated muriatic acids. It is moreover combustible, and may be decomposed by heat; giving then hydrogen gas, and carbonic acid gas, besides an acid spirit, and an empyreumatic oil. It also

contains a large quantity of carbon. The density, or quantity of matter, contained in a certain volume of this fibrous part, is variable in different plants and their parts. It is most abundant in all the several species of wood; less in herbs.—Flax and hemp, after all other principles capable of extraction have been removed, are fit subjects for undertaking an experimental enquiry into its nature.

Extracts from Plants.

§ 817.

If certain parts are separated from the plants by a proper menstruum, and brought within a smaller compass by evaporating the solvent, the remaining substance is then called an *extract* (*extractum*). (§ 77.)

§ 818.

The extracts of the same plant differ from each other according to the various nature of the extracting medium. For this purpose either water or alcohol, or both, are made use of. *Water dissolves* acid-saline, sweet, bitter, mucilaginous, astringent, ethereal-oily, acrid, and narcotic parts. *Spirit of wine dissolves* resinous, sweet, astringent, ethereal-oily, camphoraceous, acrid, and narcotic parts. There are, however, several principles, which by themselves are insoluble in water, and spirit of wine,

wine, yet may be dissolved in either menstruum, when combined with other matters.

§ 819.

In consequence of these phenomena, extracts are divided into *aqueous* or *gummy* (*extracta aquosa, gummosa*); *spirituous* or *resinous* (*extracta spiritiosa, resinosa*); and, lastly, *mixed*, or of both kinds together (*extracta mixta*).—In this place we can only treat of the first species.

§ 820.

Since the ethereal oils, the camphoraceous, acrid, and narcotic principles fly off, and are lost by decoction with water, and subsequent evaporation of the solution; which process, in the present point of view, is called extraction, it is obvious that vegetable matters, whose efficacy is owing to those matters, are unfit for making extracts from them. Under such circumstances it is better to employ the infusion itself (§ 78.), without evaporating it.

§ 821.

The way of proceeding, in the preparation of common extracts, is to reduce the vegetable body to small pieces; to boil it with water; to repeat this boiling several times with fresh water; to strain the decoction; to let it grow clear by standing; and lastly to evaporate it with a moderate heat, until
it

it is of due consistence. Towards the end of the evaporation particular care is to be taken, that the extract be not tainted with empyreuma.

Of the extracts of *La Garaye*.

§ 822.

Another method of making extracts is, by inspissating the juices expressed from plants recently collected: in other words, by reducing them, by a gentle heat, to the thickness required. From what we have said of the proximate constituent parts of plants before treated of, there can be no doubt but that extracts, prepared in this manner, may often consist of parts quite different from those that are contained in extracts made by the decoction of dry plants (§ 821).—The inspissated juices of fruits, and of some sweet roots, are denoted by the term *rob*.

Vegetable Pigments.

General Principles of the Art of Dyeing.

§ 823.

A great number of plants, or their parts, communicate their colour to water, employed for their extraction by infusion or decoction, and also to any other suitable extracting medium. The extractive principle which imparts the colour, is named *colouring matter*,

matter, or *pigment*, to distinguish it from that perception which we call *colour*.

§ 824.

The *art of dyeing* *, or the art of imbuing stuffs with various pigments afforded by the vegetable, mineral, and animal kingdoms, is a particular branch of the technical or applied chemistry, and is wholly dependent on chemical principles.

* This branch, so essential in manufactures, has been, after *Hellet*, *Macquer*, and *Poerner*, treated of in a masterly manner, according to the principles of modern chemistry, by *Berthollet*, in *Elements de l'Art de la Teinture*, Paris, 1791, 2 vols.; and lately in England by *Dr. Bancroft*.—Ed.

§ 825.

The *pigments* of the *vegetable kingdom* are not particular component parts of a peculiar kind, requiring to be distinguished from those which we have already examined; but they belong to one or the other, or they are a mixture of several. They are distinguished from the others by nothing else but by having colour; this, however, does not justify the considering them as distinct radicals.

§ 826.

The manner and cause by which pigments excite the perception of colour is an object, the investigation

gation of which properly belongs to *physics*, or natural philosophy. I only observe in this place, that by adopting a chemical composition of light (§ 189. 190.), and its decomposition by the pigment, it may be satisfactorily explained why the latter exhibits a colour.—But from the change of colour produced in any body by its absorbing oxygen, or by the escaping of this from it, we are not entitled to consider oxygen as the general colouring or discolouring principle.

§ 827.

Such pigments as, either dissolved by water alone, or by its combination with other menstrua, are contained in the *colour-baths* or decoctions, insinuate themselves into the surface, or even into the substance of the stuffs, tinged by them, and are consequently thus separated from the water. It must therefore be granted that there subsists an attractive power among such stuffs and the pigment, greater than that, which the solvent medium has for the pigment.

§ 828.

But the nature of the stuffs to be dyed causes a great difference in their attraction for pigments.—Thus it is known by experience, that wool takes the colour, or may be dyed with most ease, silk with more difficulty, still more so linen cloth, and cotton. Hence various preparations and treatments
of

of the stuffs become necessary, to make them fit for receiving the tinge. A colour, for instance, which is lasting on wool, is not, on this account, likewise permanent on cotton; and therefore the very same pigment demands various processes, according to the various kinds of stuffs.

§ 829.

Those pigments, whose colour is so durable as not to fade by washing, or in the air, or the sun's rays, or after a great length of time is but little faded, are said to be *true*, solid, fixed, or *permanent dyes*. By the term *false*, spurious *dyes*, pigments are denoted which give but little resistance, if at all, to the actions of air, sun, and water, and fade by their influence, or disappear entirely.

§ 830.

Most of the usual pigments may, indeed, be extracted or dissolved by simple water, yet some are quite incapable of such solution, and require the assistance of other solvents to afford a colour-bath. For this reason pigments have been divided into mucilaginous, resinous, glutinous, &c. But this classification is useless; because, in the present state of knowledge, the nature of few pigments only is well ascertained, and several of them are *mixed extractive matters*.

§ 831.

§ 831.

Yet the division into *substantive* and *adjective pigments*, lately proposed by Dr. Bancroft, seems to be of practical utility. The first are such as are taken up from the bath, by the stuffs not previously prepared or macerated. The second are those which do not adhere of their own accord, or are not absorbed by the stuffs out of the baths, unless they be first soaked in another substance called a *corrosive, mordant*, or macerating medium, which serves as a bond of union between the pigment and the stuff. The number of the last kind of pigments is far the greatest.

§ 832.

The adjective pigments (§ 831.) may most frequently be extracted by mere water, which they readily impregnate with their colour, and afford clear solutions. They appear by this to be mostly of a mucilaginous nature.

§ 833.

The substances used to macerate the stuffs, for making them capable of imbibing adjective pigments, are almost all of an acid-saline matter. Of this class are, sulphat of alumine (§ 416.); acidulous tartrate of pot-ash (§ 660.); the solution of tin in nitro-muriatic (§ 581.), and oxygenated muriatic acid (§ 567.); the vegetable astringent principle

principle (§ 719.); acetite of alumine; fulphat of copper, or blue vitriol; fulphat of zinc, or white vitriol; acetite of copper, or verdigris; and arsenic.

§ 832.

The way in which these *mordants* exert their efficacy, consists *partly* in their surrendering a portion of their oxygen, whereby the substance of the stuffs is altered, and hence their attractive power for the pigment increased; *partly* in their changing, in like manner, the nature of the pigment itself, and making it coagulate.—On this account, the colours of the pigments suffer various alterations by these intermedia, and receive various *shades*, or degrees of brightness, or darker hue.—Which of the mordants may be best for any particular pigment, or desired shade of colour, and for a particular kind of stuff, can be pointed out by experience only.

§ 835.

Blue, red, and yellow, are considered as the fundamental or principal colours.—By combining these with each other in various proportions (*chiefly* on the *stuffs* themselves, *rarely* in the *bath*), as also by using mordants, and of these, either acid or alkaline substances, the stuffs are tinged, not only with all the intermediate, but also with various shades of the chief colours; and a wonderful variety of tints is produced.

List

List of the principal *dyes*, or colouring substances, afforded by the *vegetable kingdom* :

I. *Substantive Pigments.*

1. *Blue dyes*:—*Indigo* and *woad*, of which hereafter in particular: the juice pressed from the fruits of the *genista americana*, which by itself is colourless, but tinges the stuff that it is brought upon, after some time, with a fixed and lasting blue colour, the *bastard ricinus* (*croton tinctorium*), a transient (*spurious*) blue.
2. *Red dyes*:—*Safflower*, or *bastard saffron* (*carthamus tinctorius*), after it has been freed from its yellow pigment by scalding with water. The red pigment which remains requires the addition of alkali to be soluble in water; but the alkali must again be precipitated from the solution by an acid. Its colour is fading.—The leaves of the *lawsonia inermis* (not yet employed); the *archil* or *orchal* (*lichen rocella*); the *dyers* or *crawfish-eye-lichen* (*lichen parellus*).
3. *Yellow dyes*:—*Arnatto* (*bixa orellana*), which will be treated of hereafter. The roots and bark of the *berberry-shrub* (*berberis vulgaris*): very fading.

Besides, *logwood* or *campeachy wood* (*haematoxylon campechianum*); *brasil-wood* (*caesalpinia sappan*), giving a brown red; *nut-galls* (*cynipidis nidus*); the *green husks* of *walnuts* (*juglans regia*); *sumac* (*rhus coriaria*); *alder-tree* (*betula alnus*); *tormentil-root* (*tormentilla erecta*): giving brown and fallow colours.

II. *Adjec-*

II. Adjective Pigments.

1. *Blue colours*:—Logwood and brasil-wood (*haematox. campech. & cæsalp. sapp.*) with pot-ash; elder-berries (*sambucus ebula*); whortle-berries (*vaccinium myrtillus*); privet (*ligustrum vulgare*); the roots of dyer's bugloss (*anchusa tinctoria*): all with pot-ash.
2. *Red colours*:—Madder (*rubia tinctorum*); fernambouc (*lignum fernambuci*), the finest and dearest species of brasil-wood; red Saunder's-wood (*pterocarpus santalinus*); the grey-blue spotted lichen (*lichen saxatilis*); the roots of dyer's bugloss (*anchusa tinctoria*).
3. *Yellow colours*:—The bark of quercitron (*quercus nigra*); fustic wood (*morus tinctoria*); dyer's weed (*reseda luteola*); common saw-wort (*ferratula tinctoria*); turmeric root (*curcuma longa*); French berries, or graines d'Avignon, (*rhamnus infectarius*); dyer's green weed, woad-waxen, or dyer's-broom (*genista tinctoria*); fenugreek seed (*trigonella fœnum græcum*); camomile with serrated winged leaves (*anthemis tinctoria*); peels of onions (*allium cepa*); safflower (*carthamus tinctorius*); narrow leaved Canada golden rod (*solidago Canadensis*); French marigold (*tagetes patula*), with an open subdivided stalk; the seeds of meadow-trefoil (*trifolium pratense*); and the seeds of snail trefoil, or lucerne feed (*medicago sativa*).

Of Indigo.

§ 836.

Indigo (*pigmentum indicum*) is a blue pigment, which is obtained as a fecula from *anil*, or indigo plant, in the East and West-Indies.—Three species of this plant are cultivated in America; *indigofera tinctoria*, *ind. disperma*, and *ind. argentea*. The two last yield less, but better indigo; the first is cultivated in the greatest quantity.—Before it blossoms, the stalks along with the leaves are cut off several inches above the ground; and as soon as they have been cleansed from adhering sand and earth by rinsing, they are put in the *soaking vat*, kept down with wooden cross-pieces, covered with water, and left standing in the shade.

After a short time, a kind of fermentation takes place, attended with sensible heat; air-bubbles arise, and on the surface of the water a pellicle appears, of a colour inclining to that of copper. Particular attention is to be paid, that the fermentation be not carried on too far, and pass into putrescence; else all the indigo would be lost. Yet at the same time it should not be interrupted too early, as otherwise too little indigo is obtained.

For

For this reason a handful of the plant is every five minutes taken out of this first vat; and if it be found that the points are soft and pale, or that the larger leaves become faint, the greenish liquor is immediately drawn off from the herb into the *stirring vat*, where it is incessantly stirred with wooden crutches and shovels to put it into strong motion. During this operation the liquor lets fall a blue flocculent sediment, and its green tinge is changed to yellow. The separation of this fecula, which is the indigo, is promoted by adding more fresh, cold, clear, and limpid water, to the fluid contained in this second vat; and a greater quantity of indigo is also produced by this management.

If then a portion of the liquid be taken out for trial, and no sediment formed, after lime-water has been added to and shaken with it, it is a sign that all the indigo is separated.—The indigo is then suffered completely to subside in the stirring-vat, and the clear incumbent fluid is drained off as closely to the fecula as possible, by cocks placed in holes bored at different heights. After this the sediment is laded into conical linen bags, and washed with cold water, which is suffered to drip off, by hanging them in the shade, in wooden cases; and thus the indigo is completely dried.

§ 837.

The various sorts of indigo met with in trade are not all of equal goodness.—It may be divided into three assortments; the *blue*, the *violet*, and the *copper-coloured*. It is better, the purer and lighter it is. The best, coming from *Guatamala*, is blue, not covered on the outer surface, or when broken, with a white crust; and so light, that it swims on water.

§ 838.

Besides the *anil*, other different species of plants also yield, by a similar treatment, a blue fecula or sediment, entirely resembling indigo.—One of these is *woad* (*isatis tinctoria*), which in Germany, long before the indigo was known, was used for dyeing blue, and is even at present employed, with the addition of indigo.—For this purpose fresh leaves of woad are collected in a dry season, washed, suffered to wither in the air, bruised, formed in roundish lumps, dried, and thus sold by the name of *woad*. By this process the leaves undergo a kind of fermentation, whereby the indigo which they contain is separated, remaining simply mingled with their pulp. The want of uniformity in the fermentation, throughout the whole mass, and the uncertainty with respect to its proper limits, are the reason that the effects of this dyeing material are neither

ther of a determined hue, nor can be relied on for durability.

§ 839.

A true indigo may likewise be prepared from woad, by the same method as prescribed for the indigo plant (§ 836).

§ 840.

A new plant, from which, according to *Roxburgh's* discovery, an indigo may be extracted, is an East-Indian tree, which he calls *nerium tinctorium* (*rose-bay*), and whose leaves contain this pigment. But the manner of preparing it varies from the usual procedure.—The indigo is extracted from it by hot water, and without fermentation.—A copper boiler is filled with the leaves, without pressing them down, and water affused upon them, to fill the vessel to within a few inches below its brim. The matter is next quickly heated to about 150 or 160° Farenh. at which temperature it is kept, with unabated stirring. When the fluid in the boiler exhibits a dark green colour, it is strained through a sieve into the stirring-vat; and while yet warm, agitated for some minutes, with the addition of $\frac{1}{3}$ of clear lime-water. The indigo then separates, and is farther treated like common indigo.

§ 841.

Of all the proximate constituent parts peculiar to vegetable substances, that we have at present ex-

aminated, indigo appears, with respect to its mixture, to come nearest to gluten (§ 744), or to the albuminous matter (§ 751); though in some points it plainly shews its difference from both.

§ 842.

Pure indigo, if distilled by itself, emits carbonic acid and hydrogen-gas, and yields ammoniac and empyreumatic oil. The residuum of the distillation is a coal, of difficult incineration, which affords but a small quantity of ashes, and contains some iron.—According to *Berthollet*, indigo consists of much carbon and hydrogen, some azot, some oxygen, and a little iron, which he estimates at $\frac{1}{30}$ of the weight of the indigo.

§ 843.

Neither water nor spirit of wine dissolve indigo; both take up from it merely an extractive matter, foreign to it, and thus leave it the purer. Nor is indigo dissolved by fat or by ethereal oils, by the muriatic and by vegetable acids.

§ 844.

Concentrated sulphuric acid dissolves indigo. It attacks this pigment with heat and ebullition, and sulphureous gas is extricated. The mixture has a blackish appearance, but becomes a beautiful blue by dilution with water. This diluted solution is in time deprived of all its colour, and in general it may
be

be remarked, that the addition of oxygen renders the colour of it less durable, and makes it at last entirely disappear.

§ 845.

Both the nitric and the oxygenated muriatic acids destroy the colour of indigo. According to *Woulf's* experiment it is inflamed by the first, if concentrated; but if weakened, the solution is blue, loses soon its colour, turns brownish, and deposits a flocculent brownish matter.

§ 846.

The dyers use various methods of precipitating the indigo on the stuffs.

The most important of these is the *woad-vat*, as it is called. Woad (§ 839) is made disposed to fermentation in water, at a convenient temperature, and by adding wheaten bran and madder. Indigo and burnt lime are next added.—In this way the indigo is, by the fermenting vegetable matters, deprived of part of its oxygen, and dissolved by the assistance of lime. The liquid is green, but is covered on the surface by a pellicle of a blue or cupreous colour. The cause of this last is, that the dissolved indigo, by attracting again oxygen, is rendered blue, and loses its solubility in the fluid.—The stuffs steeped in the vat come out greenish, but are changed to blue in the air. This vat is em-

ployed for *woollen stuffs*; and it may be kept working for a considerable time, if after each dyeing some fresh quicklime and indigo be added.—Yet, if the fermentation be not most carefully regulated, it may easily be overdone, and begin to putrefy, in which case all the pigment is destroyed.

Silk is dyed in a vat, where indigo (without addition of woad) is dissolved, with the assistance of a proper degree of warmth, along with pot-ash, vegetable ferments, bran, and madder. The solution looks green, and a scum, of a blueish coppery tinge, floats on its top.

A cold blue vat, or bath for *cotton*, is made from indigo finely levigated with water, or an alkaline lixivium, to which burnt lime, previously flaked and diluted with water, and some fulphat of iron, are added. On this mixture a part of the calcareous earth unites with the sulphuric acid of the vitriol, while the calx or oxyd of iron is precipitated. This oxyd robs the indigo of its oxygen, by virtue of its stronger attraction for this acidifying principle; and the indigo is thus, and by the assistance of the residual disengaged calcareous earth, rendered soluble. The fluid becomes also green, like the preceding, yet inclines gradually to yellow, and is covered with a film or pellicle of a blueish coppery tinge.—The stuffs are dyed in this vat, after the coarser particles have subsided. They are taken out
of

of a yellowish colour, which on exposure to air, owing to the indigo absorbing again oxygen, changes through various shades from green to blue. It is proper to acidulate the last water, in which the stuff is rinsed, with a little sulphuric acid.

For *linen goods* a vat is prepared, with a lye of caustic pot-ash, wherein the indigo is boiled with orpiment (sulphurated arsenical oxyd), till the bath be green, exhibiting at the top a copper-coloured pellicle.

Finally the *Saxon-blue*, used for dyeing *silks* and *woollen stuffs*, belongs to this place. The method of operating is indeed very commodious, and saving of expence, yet attended with the great disadvantage of becoming thereby less permanent, and fading much sooner. For dyeing in this manner, from 5 to 8 parts of sulphuric acid are gradually poured on one part of finely pulverized indigo. Heat is produced by the mixture; the indigo decomposes a part of the acid, which on that account escapes as sulphureous acid; while the carbon of the pigment likewise absorbs a portion of oxygen from the sulphuric acid, and flies off in the form of carbonic acid gas.—The mixture is left standing for 24 hours; the solution is then largely diluted with water, and used for dyeing.

Concerning

Concerning Litmus.

§ 847.

Litmus is another blue pigment, which, according to *Ferber*, is most probably prepared from the moss called *archil* or *orchal* (*lichen roccella*, *orseille*), and from the *dyer's lichen* (*lichen parellus*) *. The moss is steeped in wooden cisterns, in urine, lime-water, flaked lime, and some pot-ash, or soda, where it is kept under shelter. Now and then it is agitated, and suffered to macerate, till it begins to ferment in some degree. This fermentation, which must not be permitted to pass into putrefaction, is kept on, until the moss be converted into a blue and soft pulp, which is attenuated by grinding, forced through a hair-cloth, formed into square lumps, and dried in the shade.

* It is not so well known whether litmus be also made of the *bastard ricinus*, or *turnsole plant* (*croton tinctorium*). However, the blue turnsole rags (*tournefol en draps*), are, according to *Montet*, prepared of that plant, at *Grand-Galargues*, in Languedoc.—Ed.

§ 848.

Litmus is, strictly speaking, only so far blue, as it is combined with an alkaline substance. Its natural colour is red, and this native tinge is again restored by acids, by which the alkaline matter is
neutralized.

neutralized.—On this account the *tincture of litmus* is qualified to serve as a *reagent*.

Of Arnatto.

§ 849.

The *rocou*, or *arnatto* (§ 835), is also to be mentioned here. It is prepared from the pulp of the seed-capsules of a tree growing in Guiana, *Urucu* (*Bixa Orellana*). The seeds, together with the red tough matter surrounding them, are softened in a wooden trough with water, until, by a kind of fermentation, which spreads a very nauseous smell, and by diligent stirring and pounding, the kernels are separated from the pulp. This mass is then strained through a sieve, and boiled; whereupon a thin reddish scum, which is the pigment, separates. When skimmed off, it is carefully inspissated in another kettle, and after being completely cool, is moulded in roundish lumps, wrapt round with leaves of trees, and packed for sale.—Arnatto is not dissolvable by water, nor by spirit of wine; to be fit for dyeing, it requires an alkaline menstruum. It seems to partake of the nature of the vegetable albuminous matter.

Sap-Colours.

§ 850.

Sap-colours are either inspissated juices of plants, or extracts from them; supposing, however, that these juices are impregnated with a certain colour. Of this kind are, *gamboge* (§ 742); *sap-green*, from the *buckthorn-berries* (*rhamnus catharticus*), not perfectly ripe; the extracts of *fernamboue* wood, of *saffron* (*crocus sativus*, or *orientalis*); of *green walnut-husks* (*nux juglans*); the juice of *whortle-berries*, thickened by boiling; the inspissated juices of *honeysuckle* (*lonicera xylosteum*); of the American *night-shade* (*phytolacca decandra*), and others. The tints of these pigments may be greatly varied by adding acids, alkalis, and other salts.

Lake-Colours.

§ 851.

Freshly precipitated argillaceous earth readily absorbs the mucilaginous colouring parts of plants; or it retains them, and is by them coloured. On this fact the preparation of several *lakes*, or *lake-colours*, is founded. Of lakes of a baser and coarser fort, the calcareous earth is the basis.

§ 852.

The *counterfeit florentine lake* may serve as an example to shew in what manner lake-colours are made. Equal parts of fernambouc, or the finest brasil-wood, and sulphat of alumine, are boiled in a sufficient quantity of water. The decoction is then strained, and a lye of pot-ash added, till the alum is duly decomposed; taking care, however, that the quantity of the alkali be not in excess. Lastly, the precipitate is separated from the fluid by filtration; is laid on paper in the form of small cones, by means of a funnel, and dried with haste.

The genuine *florentine lake* is obtained, as well as *carmine*, from an animal pigment, the *cochineal*. Of this we shall speak hereafter.

§ 853.

By the same method other sorts of lakes may be manufactured from various tinging vegetable bodies; viz. by precipitating their strained decoction, made with alum and water; the precipitant is again a fixed alkali. Or by inverting the process, the decoction is made with alkali and water, and the lake-colour precipitated by an aqueous solution of sulphat of alumine; best, while warm. To this class belong, *madder-lake* of Marggraf; *Neri's yellow lake*, from the *dyer's-broom* (*genista tinctoria*); another *yellow lake*, from the *quercitron-bark*; the *lakes* after the manner of Scopoli; the *Dutch-pink*

(*stîle de grain*), from the decoction of turmeric with alum, and decomposed by chalk; and others.

Of Bleaching.

§ 854.

The *bleaching* of stuffs and other bodies rests on this circumstance, that vegetable colours are destructible by the joint actions of air, moisture, and light; or rather on the alterations which the mixture of pigments undergoes by the influence of these causes. The stuffs are for that purpose first liberated from the adhering grosser and extractible particles, by which they are coloured. This is effected by boiling them in an alkaline lye; after which they are exposed, with the greatest possible surface, to the action of the sun's rays, keeping them continually moist.—It agrees pretty well with the theory, that besides this process, weakly sour liquids, as *whey*, and *very much diluted sulphuric acid*, may be serviceable to promote the bleaching.

§ 855.

For it seems to be at present placed beyond any doubt, that the pigment with which the stuffs are impregnated, or the fibrous ligneous part itself, is deprived of its colour by absorbing oxygen. And in this circumstance the efficacy of bleaching is to be sought for, as is abundantly confirmed by the
analogous

analogous action of oxygenated muriatic acid; which, by ceding part of its oxygen to coloured vegetable substances, deprives them of their colour (§ 570).

§ 856.

This remarkable property of oxygenated muriatic acid has been already resorted to, with the greatest advantage, in the bleaching of linen and cotton yarns in great quantities; as they may be restored by it to whiteness in a much shorter time, and at any season. *Berthollet* * has described the proceeding and the apparatus to be employed in the large way.—In my opinion it would be an advantageous alteration in this method of bleaching, if, instead of oxygenated muriatic acid itself, an alkaline lye, completely saturated with that acid, were employed; it being much easier to impregnate this lixivium with it than simple water.

* See *Annales de Chimie*, tom. II. p. 251, seq. and tom. VI. p. 204, seq.—Ed.

“ To perform the bleaching upon this principle,
 “ *Chaptal* proposes to steep the linen, or cotton, in
 “ a weak alkaline lye, and to boil it with it. After
 “ this process they are taken out and wrung. When
 “ thus freed from the superfluous moisture, they are
 “ either exposed for a little while, and with the
 “ greatest possible surface, to the vapours of the
 “ elastic oxygenated muriatic acid (§ 569); or,
 “ better,

“ better, they are immersed in a liquor composed
 “ of that acid in a condensed state, and diluted
 “ with water. During this they should be stirred
 “ and wrung. Lastly, the unpleasant odour with
 “ which they become impregnated, is removed by
 “ washing them in large quantities of water. The
 “ addition of alkali in the lye has been thought ne-
 “ cessary to neutralize the acid, and prevent its cor-
 “ rosive effects, by which the stuffs themselves might
 “ be destroyed.—As Dr. *Gren* justly remarks, it is
 “ desirable that the health of the workmen were
 “ less endangered in this process; and the advan-
 “ tageous alteration which he proposes, by impreg-
 “ nating the alkaline lye itself with the acid, is the
 “ contrivance of *Pickel*.”—Ed.

In this country *Theophilus Rupp* has given a simple appa-
 ratus, and method of bleaching with oxygenated
 muriatic acid, without the addition of alkali; and
William Higgins, chemist to the linen-board of Dublin,
 recommends to substitute sulphuret of lime for pot-
 ash in this process.—See *Nicholson's Journal*, vol. II.
 p. 268; vol. III. p. 253.—Ed.

END OF VOL. I.

PLATES,

REPRESENTING

SOME OF THE MOST NECESSARY

CHEMICAL INSTRUMENTS.

VOL. I.



Fig. I.

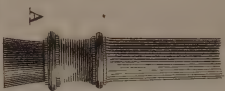


Fig. V.

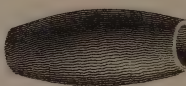


Fig. IV.

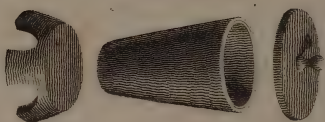
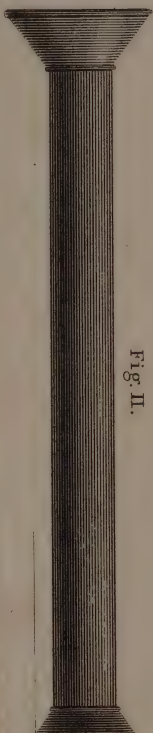


Fig. III.



Fig. II.



D

Fig. I.

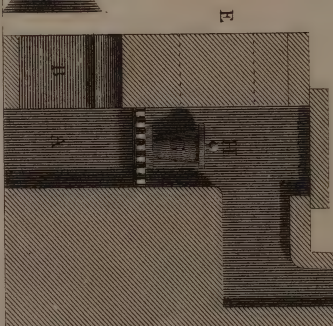


PLATE I. §§ 56, 101.

FIGURE I. *A Wind-furnace.*

- A. The ash-pit.
- B. Door to the ash-pit.
- C. A tile, to cover the fire-place.
- D. The chimney. The longer it is, the stronger is the draught of air.
- E. Here a door may be applied to the fire-place, according to the dotted lines.
- G. A crucible resting on its stand, or piece of a tile, and the grate.
- H. The fire-place.

N. B. The bars of the grate should not be shaped square and flat. They are better when formed in lozenges, placed on their edges as at (*g*), or curved, as at (*b*).

FIGURE II.

A canal, or tube, constructed of any materials, round or square, and conveying the air from a distant cool place, either horizontally, or perpendicularly, from underneath the furnace.—By this contrivance the current of air is amazingly increased.

Fig. III. A triangular *crucible* on its stand.

Fig. IV. Another ditto, round one, with a cover and stand.

Fig. V. *Affaying crucible*, bellying out in the middle.

FIGURE VI.

A *blow-pipe**, 8 or 9 inches long. It is made of brass or silver. The mouth-piece A. should be of ivory. The hollow globe B. is contrived to condense the vapours coming from the breath. The opening C., through which the wind is applied to the flame, must be as small as the finest wire.

* *Engestrœm* has explained the use of this instrument in the Appendix to his description of a *Mineralogical Pocket-Laboratory*, added to the end of *Magellan's* translation of *Cronstedt's Mineralogy*. 8vo. London, 1788. Vol. II.

PLATE II. §§ 59, 104.

Fig. I. *Reverberatory-furnace.*

- A. The *ash-pit*.—B. The *fire-place*.—C. Its *dome* and *chimney*, which is moveable, and serves to reflect the flames on the vessel, as here on the retort D. the neck of which is inserted in the balloon E. On the top of the square brick-work there is a hole near each corner, serving for a *register*.

Fig. II. *Docimastic or Assaying and Cupelling-furnace.*

- A. The *body of the furnace*, built square, from 12 to 15 inches each side, of fire-proof clay, or thick iron-plates, and terminating in a truncated open pyramid.
- B.B.B. Three strong *iron-bands*, fixed with screws, and morticed in the front for the motion of the *slides*.
- C.C.C.C. Four *slides with handles*. The semicircular and oblong *apertures* are contrived for inspecting the operation, and so placed, that when the slides are shut, or meet in the middle, they do not reach the open part of the muffle.
- D. The *ash-pit*, having in front a semicircular aperture. Immediately above it is the *grate*. Through the front plate and its opposite one behind, as also in the *middle band B.* are holes marked F.
- E. A *semicircular aperture*, of the size of the muffle.
- F. *Holes*, mentioned at D. through which *iron-bars* are inserted for supporting the muffle.
- G. A *circular hole*, by which to manage the coals.
- H. A *pyramidal cover**, with a *chimney*, that may be added or removed, and occasionally prolonged by an additional tube, in order to increase the intensity of heat.

* The fuel is put in at top. The dimensions are shewn by the scale.

- K. The *muffle* of baked clay, open in front, and closed behind. Its form is half a cylinder cut length-ways. The openings c.c.c. are to admit more heat, yet without admitting ashes.
- L. A *scorifying test*, § 102.
- M. Two *assaying tests*, or *cupels* (§ 104) of a smaller size: either of a circular as (1), or inverted, truncated, pyramidal form, as (2). On their spherical cavities the materials are placed.

* This furnace serves for assaying metals, refining gold and silver, &c. *Macquer, Elements of Chemistry*, Part I. Chap. 19, has fully explained the construction and manner of using this furnace.

Fig. I.

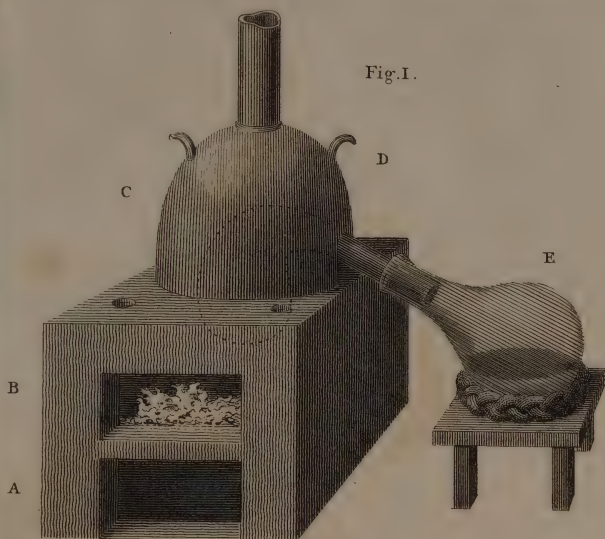


Fig. II.

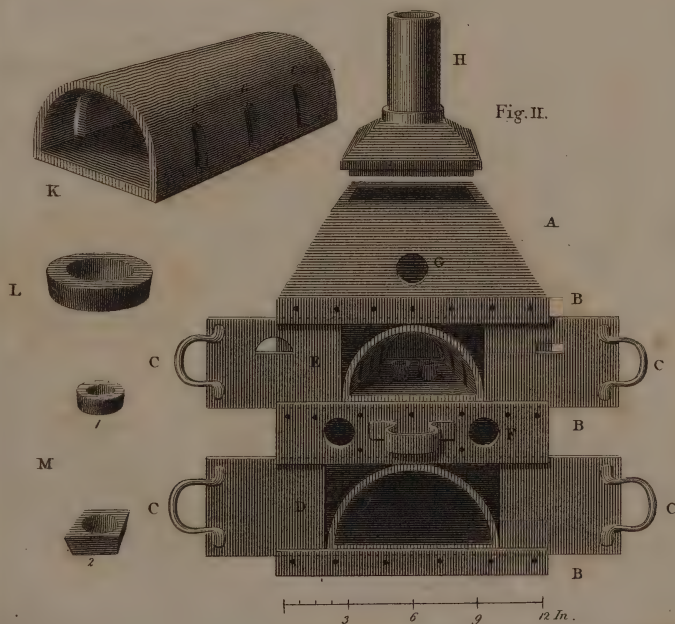




PLATE III. § 55.

Fig. I. *Portable Furnace, made of a Black-lead Crucible.*

A. The crucible, perforated on its lower part, and supported by a stand.—B. The cover of iron-plate, or tile. Its smaller circular hole serves to put in additional fuel, and to give vent to air. It may also be provided with a moveable chimney. The larger hole admits the sand-pot, and C. the retort, or other vessel.—D. Section of the furnace.—E. Section of the grate.—F. Plan of the grate, resting on three projectures, fitting into three notches cut in the body of the crucible.—(N. B. Three such points, at equal distances, are always safest.)—G. The sand-pot, which also may serve for a water-bath, or for calcining.—H. Stand.

* Crucibles, from 12 to 15 inches high, are chosen for this purpose.—See *Lewis's Philosophical Commerce of Arts*, page 1—37.

Fig. II. *Dr. Black's Furnace.*

A. *Perspective view of the furnace.* The larger hole at top serves for introducing the sand-pot, &c. and is often the mouth of the furnace. On the smaller aperture the vent, or chimney, G. is fixed.

B. *Perspective section of the furnace.*

C. The ash-pit, separable, and a little wider than the furnace, which is inserted into it, and rests on its projecting border.

D. Section of the grate, likewise resting on the border of the ash-pit.

E. *Perspective view of the ash-pit*, provided with a small door, and a damping-plate, or register, of 6 differently-sized holes.

F. A ring, with 3 hooks, to be sunk about 1 foot deep into the furnace, and on which the retort rests when distilling, &c. in open fire.

This furnace is of an elliptical form, made of strong wrought-iron. Its inside is coated in such a manner as to represent an inverted cone, and the lighter part shews the manner in which the luting is applied.—The lower opening for the grate is not in the middle of the bottom, but purposely nearer to one end of the ellipse, towards the larger aperture at top.

* The Translator particularly recommends this excellent furnace for philosophical purposes to the amateur and the student.—Its structure and use are circumstantially described in the *New Edinburgh Dispensary*, 1797, p. 48.—Furnaces of this kind, and other chemical instruments, are sold at Mr. Knight's, iron-monger, in Foster-lane.

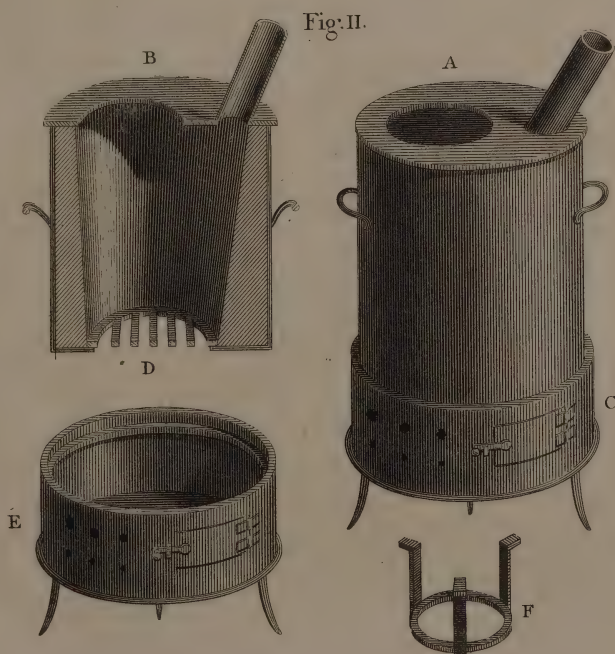
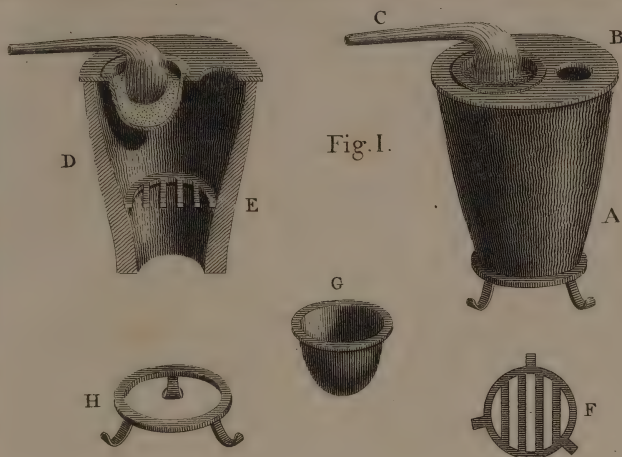
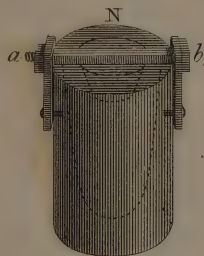
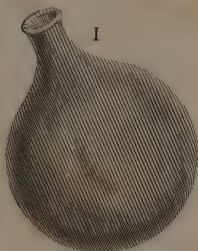
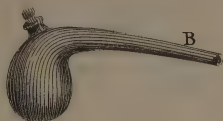


PLATE IV. §§ 79, 81, 121, 128, 131, 135.

- A. A *simple retort*, made of glass, metal, or baked clay.
- B. *Tubulated retort*, used when, on account of the too rapid extrication of gases or acids, its neck must be luted to the receiver, before the materials are introduced, or the fire applied. *Holes* are also drilled, sometimes, on the upper part of simple retorts, to let out, by opening their stoppers, the elastic fluids, when too copious.
- C. *Matrass*. The *ring* added in the manufacture to its neck, renders it capable of being suspended by a string.
- D. A *matrass*, provided with an *alembic*, or head, which at times is fixed to it in the glass-house. It then has at top an *opening* and *stopper*. A *receiver* is here added to the spout of the head.
- E. A *phial*. These also have sometimes a small head, similar to that of the *matrasses*.
- F. *Pelican* of former chemists for *cobobation*.
- G. A *proof* or *disengaging-bottle*.
- H. *Tubulated proof*, with an inserted, moveable, bent glass-tube.
- I. A *large balloon*.
- K. *Aludels* of the ancients for sublimation.
- L. *Adopters* inserted into one another.
- M. *Italian recipient* for separating *ethereal oils*. The bent neck being lower than the mouth, it acts like a *siphon* when the vessel is nearly full to the brim; and the oils, being lighter, swim on the water. Hence, by hydrostatical principles, the latter entering into the lower part of the spout flows off at top, while the oil remains.—But if the oil, as that of *cinnamon*, is specifically heavier, another funnel is sunk in, through which the oil passes to the bottom; and the water runs off by a similar side-aperture as that in the figure, but placed higher towards the brim of the recipient.
- N. *Papin's digester*, of strong metal, to the thickness of an inch. The inner bottom has an *oval* shape. A *conical lid* is fitted in by grinding, and kept down air-tight by the *cross-bar* and *screw* (a. b.) *Wilke* has given an improvement of it in the *Swed. Philos. Transf.* Vol. XXXIV. p. 3. Messrs. *Jackson* and *Myser*, of Frith-street, Soho, have imitated it with a moveable valve at top for culinary use.
- O. A *separatory funnel*, ending with a long capillary tube.



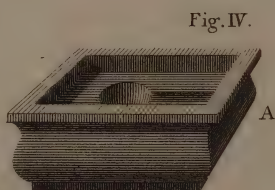
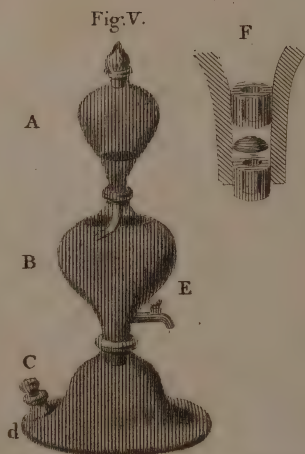
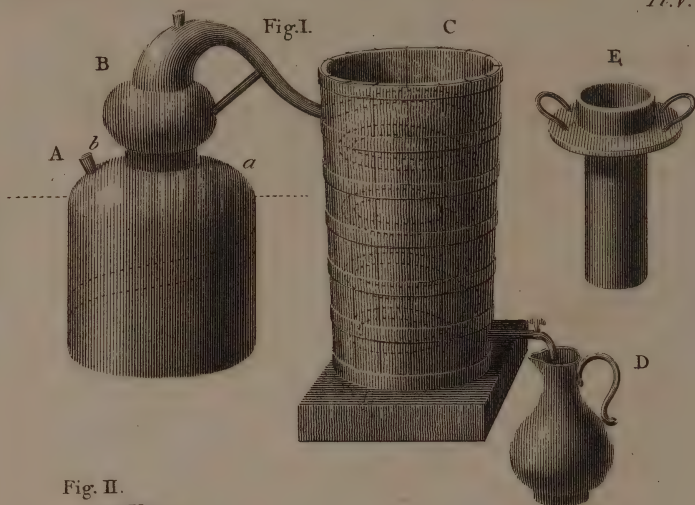


PLATE V. §§ 116—17, 126—27, 130.

Fig. I. *Common Still.*

- A. *Body of the still*, of copper, and of all sizes, to some hundred gallons. When large, it is set in brick-work up to the shoulder (*a*). The fire is applied underneath; but the flue turns round in a *spiral* manner, as shewn by the pricked-lines.
- B. *Head of the still*, provided with an aperture to let off superfluous vapours, as likewise the body has one at (*b*), to supply the fluid.
- C. *Refrigeratory*, or condensing *tub*, filled with cold water, and its *worm* marked by the dotted lines. In large works, a stream of cold water is made to run constantly through this cooling tub, as in the gin-distillery at *Maidstone*.
- D. Vessel to receive the distilled fluids coming through the cock of the worm.
- E. A copper vessel for distilling in *water-bath*. It fits into the mouth of the still; and the same head serves for both.

Fig. II. *Blackamoor's Head.*

The *Blackamoor's head* consists of a conical vessel, surrounded with another cylindrical filled with cold water, and having a cock to draw it off when become too warm. Both are of copper. Half the figure is here left open to shew the cone; the inclination of the sides of which, according to *Chaptal*, is most proper when forming an angle of 75 degrees with the base.

Fig. III. *Pneumatic Water-trough.*

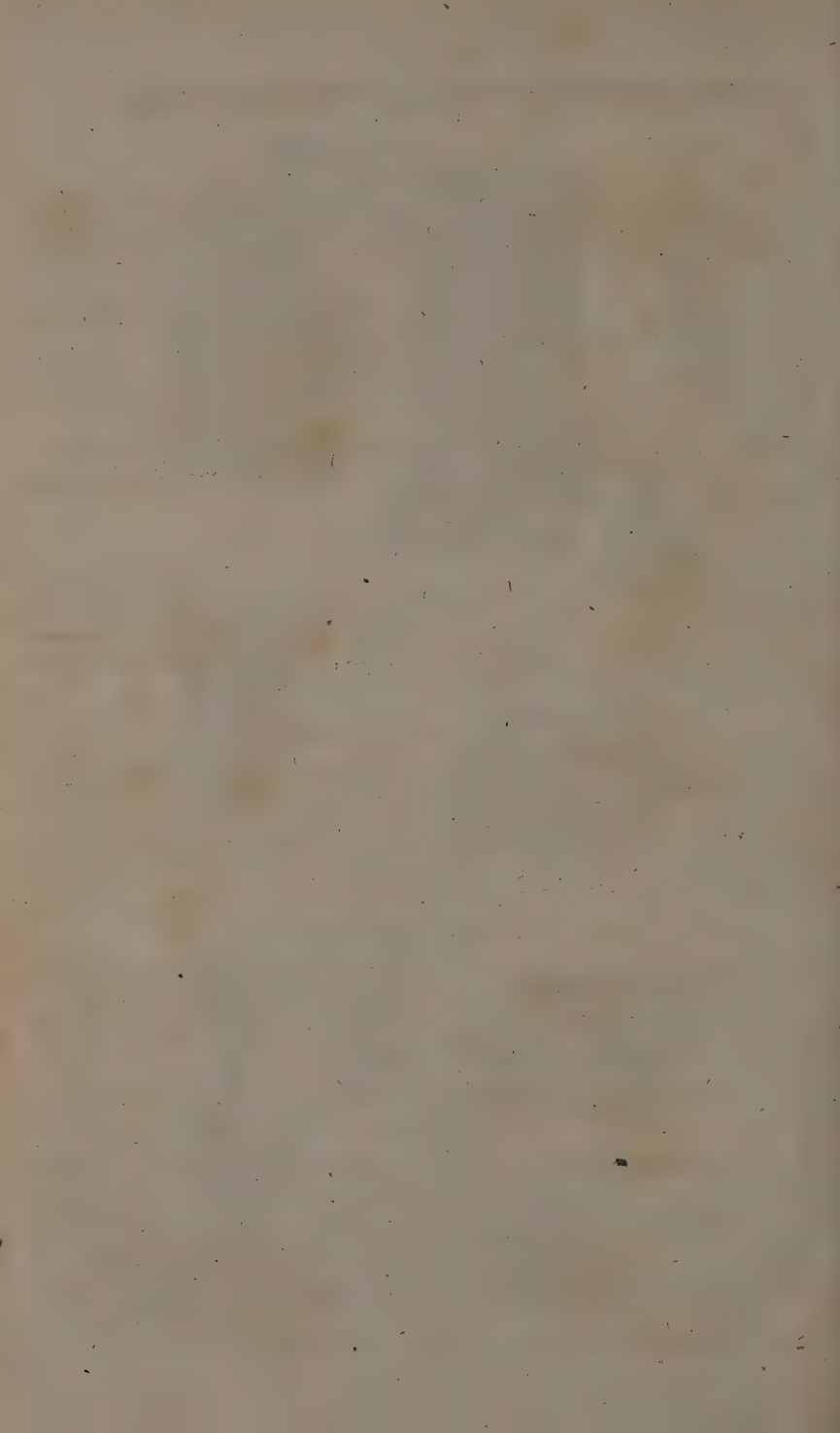
Two inches below the brim a *shelf* is fixed to about half the width of the trough, having some *holes*, of a *funnel-like* aperture, underneath. It is filled with water to within one inch from the top. A glass jar, filled with water, to drive out the air, is placed *invertedly* upon such a hole of the shelf; and the *conveying-tube* of the proof, or neck of a retort, is placed under that hole. As the gas rises, the water is driven out of the jar.

Fig. IV. *Pneumatic Quicksilver-trough.*

- A. Perspective view of the *spherical cavity* and *groove*, to be filled, and something higher, with *mercury*. The receiving-vessel is likewise filled with that metal.
- B. Its section, shewing the manner of placing the *glass-bell* and *neck* of the *retort*. This trough is mostly made of *marble*.

Fig. V. *Dr. Nouth's and Parker's Apparatus for impregnating Water with Carbonic Acid, &c.*

A. The *upper vessel*, whose neck reaches nearly to the centre of the middle one—B. which is *half* filled with *water*, and has at C. a *glass-valve*, through which the gas extricated rises. It is formed of two pieces of a broken *capillary tube*, and a *moveable plano-convex lens* between. At D. the materials are put in. Through the cock the water is drawn off, when sufficiently impregnated with the gas. All joinings are fitted by grinding.—F. represents the valve in a larger scale.—See its use in *Nicholson's First Principles of Chemistry*, 1796, p. 54.



LAVOISIER'S PNEUMATIC DISTILLING APPARATUS

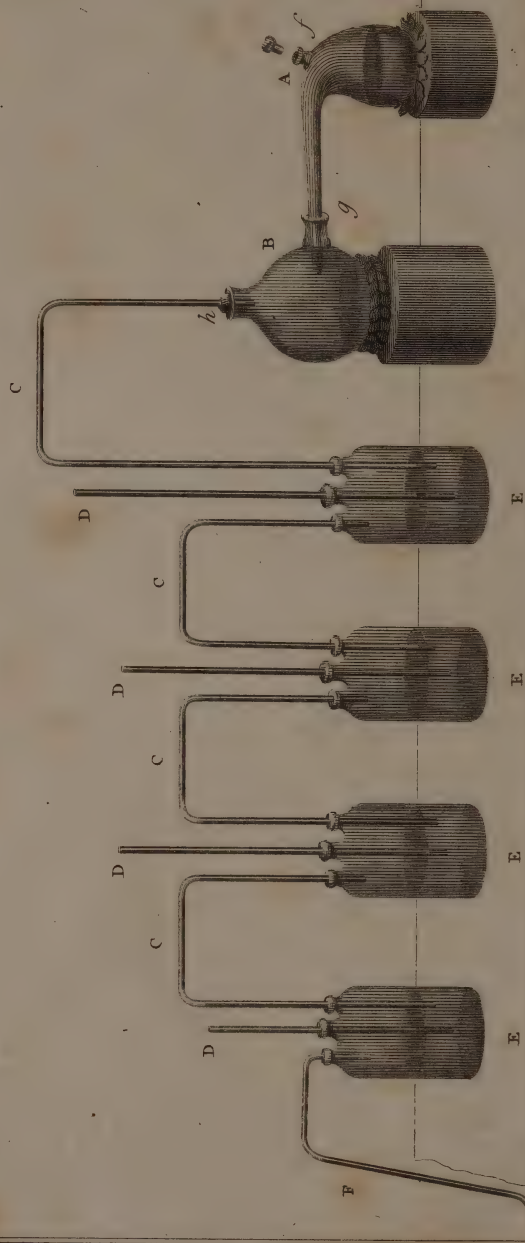


PLATE VI. §§ 123, 128.

LAVOISIER's Apparatus for Pneumatico-chemical Distillations.

- A. A *tubulated retort*.
- B. *Balloon*, serving as the first receiver.
- C.C.C.C. Bent *glass-conveying tubes*.
- D.D.D.D. *Tubes of safety*, to prevent the bursting of the vessels by the too rapid extrication of the gases.
- E.E.E.E. *Intermediate*, tubulated bottles.
- F. The *last conveying-tube*.

Through the *tubular aperture* (*f*) the substances to be examined are introduced into the retort, whose neck is joined to the balloon at (*g*).—The *right-hand side* of each conveying-tube is *shorter*, and receives the gases. That on the *left* is *longer*, and *immersed* in the liquid contained in the middle bottles E. &c.

In the *balloon* there is *no water*. But *distilled water*, of a *known weight*, is commonly put in the *first* of the bottles E.E. &c. The other *three* contain *caustic pot-ash* dissolved.

The *apertures* of the *balloon* (*g* and *h*) are luted with a *fat lute*, and *linen-cloth* dipped in *quick-lime*, beaten with whites of eggs.—For the apertures of the other bottles a lute, made of *turpentine melted with wax*, is sufficient.

And the *last conveying-tube* F. is directed under the *glass-bell*, placed on the shelf of the *pneumatic-trough*.

* For farther particulars see *Lavoisier's Elements de Chimie*, Part III. Sect. 6.
§ 1.

